

# PUBLIC POLICY EVALUATION USING LIFE-CYCLE MODELS

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## **PUBLIC POLICY EVALUATION USING LIFE-CYCLE MODELS**

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University of Pittsburgh, 2014

This work investigates how the provision of a variety of public policies affects individual life-cycle decisions. In Chapter 2, I examine the effects of the Affordable Care Act (ACA) by considering a dynamic interaction between extending health insurance coverage and the demand for federal disability insurance. I argue that as the ACA provides insurance coverage to the uninsured, it improves this group's health and reduces their demand for federal disability insurance. In order to provide a quantitative assessment of this dynamic link, I extend the Bewley-Huggett-Aiyagari incomplete markets model by endogenizing health accumulation and disability decisions. Findings suggest that the ACA reduces the fraction of working-age people receiving disability benefits from 5.7 to 4.9 percent. Chapter 3 analyzes the effects of social security survivors benefits and argues that survival benefits provide insurance against the heterogeneity of mortality rates. Specifically, the provision of survivors benefits mitigates the inequality induced by within cohort mortality differences and the associated price variations in the private life insurance market. Further, survivors benefits also help insure the uncertainties of income shocks and life events. The risk spreading provided by survivors benefits, however, is funded via taxes that distort individual decisions. Counterfactual results from a dynamic model suggest that removing survivors benefits for dependent children and aged spouses generates an ex-ante utility change equivalent to a 0.3 percent decline and 0.8 percent increase of permanent consumption, respectively. In

Chapter 4, considering that people choose both years of education and their area of specialization, I estimate the impacts of technological progress and immigration on educational choices of native-born Americans. Results derived from a general equilibrium model suggest that these two changes lead to opposite effects on educational choices. In particular, the influx of immigrants reduces natives' incentives to complete college degrees and major in natural sciences and engineering fields.

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## **PREFACE**

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## 1.0 INTRODUCTION

In order to improve the quality of life, people trade in different types of markets. Specifically, people dislike uncertainties and want to write contracts to insure against all types of risks. Since markets are not perfect, individual risks cannot be fully spread by private trading behaviors. For example, the risk of being born in families of different economic status is uninsured, because there is no such market in which unborn individuals can write contracts with each other. As a supplement to private markets, public policy is designed by the government to achieve equality and efficiency by redistributing resources and correcting market failures, respectively. Government provisions, however, are funded by taxes and distort daily decisions in a variety of ways. For instance, the implementation of the Affordable Care Act imposes extra tax burdens and distorts peoples' decisions on working, savings, and medical expenditures. The purpose of my dissertation is to design life cycle models to analyze the economic impacts of public policy. In particular I devote the following three chapters to health care reforms, social security programs, and immigration policy.

Chapter 2, titled “The Affordable Care Act in an Economy with Federal Disability Insurance”, examines the effects of the Affordable Care Act (ACA) by considering a dynamic interaction between extending health insurance coverage and the demand for federal disability insurance, which has received little attention in prior literature. This chapter argues that as the ACA provides insurance coverage to the otherwise uninsured, it improves this group's health and reduces their demand for federal disability insurance. In order to pro-

vide a quantitative assessment of this dynamic link, I extend the Bewley-Huggett-Aiyagari incomplete markets model by endogenizing health accumulation and disability decisions. The model is calibrated to match the 2006 U.S. economy and used to examine the influence of three main components of the ACA: Medicaid expansion, insurance subsidies, and an individual mandate. Findings suggest that the ACA raises tax rates, but reduces the fraction of working-age people receiving disability benefits from 5.7 to 4.9 percent. In turn, the fiscal changes associated with disability decisions help to fund 47 percent of the ACA's cost. Results also indicate that an alternative plan without Medicaid expansion reduces tax burdens and improves welfare relative to the full package of the ACA.

Chapter 3, titled “Economic Analysis of Social Security Survivors Benefits”, analyzes the impacts of social security survivors benefits, a federal program that has received little attention in the literature. I argue that survivors benefits provide insurance against the heterogeneity of mortality rates. Specifically, the provision of survivors benefits mitigates the inequality induced by within cohort mortality differences and the associated price variations in the private life insurance market. Further, survivors benefits also help insure the uncertainties of income shocks and life events. The risk spreading provided by survivors benefits, however, is funded via social security taxes that distort individual decisions. To evaluate the effects of survivors benefit programs, this chapter introduces a dynamic model, in which heterogeneous agents make decisions on consumption, bonds, and life insurance holdings. Counterfactual results suggest that removing survivors benefits for dependent children generates an ex-ante utility loss equivalent to a 0.3 percent decline of permanent consumption, but removing survivors benefits for aged spouses produces an ex-ante utility gain that equals a 0.8 percent increase of permanent consumption.

Chapter 4, titled “Technological Progress, Immigration, and Educational Choices”, studies the effects of technological progress and immigration on educational choices of native-born Americans. Education is a multidimensional choice: people choose both years of education and their area of specialization. To characterize the associated trade-offs,

this chapter builds a general equilibrium model with heterogeneous agents who are differed in two types of abilities—quantitative abilities (the ability to reason and analyze) and interactive abilities (the ability to communicate and negotiate)—and make decisions on college attendance and the major of specialization. College education yields positive returns on both ability endowments, and majoring in natural sciences and engineering (NSE) fields induces higher returns on quantitative abilities but at the cost of lower returns on interactive abilities compared to other majors. The model is calibrated to match the 1969 US economy and used to simulate the long-term effects of the observed technological and immigration changes for the period of 1969 to 2006. Results suggest that these two changes lead to opposite effects on educational choices. In particular, the influx of immigrants reduces natives’ incentives to complete college degrees and NSE majors. Overall, the effect of technological progress dominates that of the immigration shock, and thereby results in more native-born Americans completing college degrees and more college graduates having NSE majors.

## 2.0 THE AFFORDABLE CARE ACT IN AN ECONOMY WITH FEDERAL DISABILITY INSURANCE

### 2.1 INTRODUCTION

The ACA is the most significant change in the U.S. health care system since the passage of Medicare and Medicaid in 1965. One of its principal objectives is to increase the rate of health insurance coverage for Americans by subsidizing the purchase of health insurance through an insurance exchange, expanding state-operated Medicaid, and imposing mandates on health insurance coverage. The challenge of the new policy is to extend coverage while containing the cost of health care provision. According to the 2012 CBO estimates, the net cost of insurance coverage provisions of the ACA is \$1,168 billion for the period of 2012-2022.<sup>1</sup>

The starting point of this paper is the observation that provisions of the ACA are likely to interact with pre-existing government programs. The specific program I focus on is federal disability insurance programs under which individuals deemed “disabled” receive cash benefits and gain access to Medicare.<sup>2</sup> In 2011, 9.0 million people aged 18-64 received federal disability benefits, that was 6.2 percent of the US residents aged 18-64. The total cost was about \$150.3 billion. In this paper, I argue that the ACA, by

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<sup>1</sup>More details about the ACA are available in Section 2.2.1 and the Public Law 111-148 <http://www.gpo.gov/fdsys/pkg/PLAW-111publ148/pdf/PLAW-111publ148.pdf>.

<sup>2</sup>There are two types of federal disability insurance: the Social Security Disability Insurance (SSDI) and the Supplemental Security Income program (SSI). More details are available in Section 2.2.2.

extending health insurance coverage to the uninsured, will improve this group’s health capital, reduce the relative value of in-kind Medicare benefits, and lower the chance of receiving federal disability assistance.<sup>3</sup> In addition to the partial equilibrium effects, the ACA also affects the demand for disability insurance via general equilibrium channels. For instance, the extension of health insurance coverage lowers people’s precautionary saving motives, the capital stock of the economy, and thereby the market wages. Moreover, the implementation of ACA directly influence government expenditures and indirectly affect the equilibrium tax rate. The shifts of market wages and tax rates impact the disability option through changing its opportunity cost. The contribution of this paper is to design a general equilibrium model that captures the above mentioned mechanisms. The model is used to evaluate the effects of the ACA on a broad set of variables, including the government budget, measures of labor supply, income, and welfare.

In order to provide a quantitative assessment of the ACA, this paper extends the Bewley-Huggett-Aiyagari incomplete markets general equilibrium framework to allow for endogenous decisions of health capital and disability.<sup>4</sup> To the best of my knowledge, this is the first paper that endogenizes both choices. The quantitative analysis of the model yields three main findings. First, the ACA reduces the fraction of working-age people receiving disability benefits (hereinafter referred to as disability rates) from 5.7 to 4.9 percent. Second, the ACA reduces government spending on disability assistance and increases government revenue through enlarging the labor force. For every 100 dollars the government spends on the ACA, it saves 32 dollars on disability insurance and 8 dollars on Medicare for people with disabilities, and raises tax revenue by 7 dollars via enlarging the tax base. Last, I find that an alternative health care reform plan that, contrary to the ACA, did not expand Medicaid coverage would reduce the equilibrium tax rate and improve welfare.

The model is characterized by heterogeneous agents who make dynamic decisions on

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<sup>3</sup>This argument is supported by empirical evidence found in [Maestas et al. \(2012\)](#)

<sup>4</sup>See [Bewley \(1986\)](#), [Huggett \(1993\)](#), and [Aiyagari \(1994\)](#).



disability, insurance, consumption, savings, leisure, labor, and medical expenditures. The marginal cost of medical services differs by insurance status. Uninsured agents facing a high price purchase few medical services, have low health capital, and are more likely to claim disability benefits. Key parameters of the model are calibrated to match the 2006 US economy, one year before the Great Recession. The calibrated model successfully matches data along several important dimensions that are not targeted, such as health related statistics, the variation in the demand for disability insurance by education and age groups, and life-cycle changes of good consumption, medical expenditures, and working hours. It is also important to note that this model outperforms other models with endogenous health accumulation by producing a long-tail in the distribution of both total and out-of-pocket medical expenditures.

The model is used to examine the long-term effects of the ACA, which includes Medicaid expansion, insurance subsidies, and an individual mandate. Besides the main findings as previously stated, following the ACA, the labor force participation rate increases by 0.9 percent. This increase offsets reductions in working hours and capital and leads to a 0.2 percent rise in output. The ACA also causes the fraction of working-age people without health insurance (hereinafter referred to as uninsured rates) to drop from 18.1 to 0.1 percent. In spite of the depicted benefits, the ACA produces a welfare loss equivalent a 0.3 percent decline of permanent consumption.<sup>5</sup> This observation is consistent with the argument of [Feldstein \(1973\)](#) that the negative effect of moral hazard behaviors associated with low coinsurance rates outweighs the positive effect of risk spreading. On the contrary, an alternative plan excluding Medicaid expansion induces a welfare gain equivalent to a 0.2 percent increase of permanent consumption. This is because compared to the ACA, the alternative plan substantially reduces the number of Medicaid patients and the associated overuse of medical services. Last, in order to determine the importance of the proposed dynamic interaction, I compare the results of the baseline model to an alternative model, in

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<sup>5</sup>This loss is not a small number in macroeconomic analysis, since the welfare loss from business cycles is equivalent to a 0.05 percent decline of permanent consumption ([Lucas, 2003](#)).

which federal disability insurance programs are removed. Results suggest that omitting the dynamic interaction leads to underestimates of the benefits and overestimates of the costs of health care reforms. In particular, the fiscal and welfare costs of the ACA simulated by the alternative model are 81.3 percent larger than those simulated by the baseline model.

This paper is related to five strands of literature. The first strand of literature analyzes how the 1984 disability reform that liberalized disability screening process changed the nature of federal disability insurance programs (Autor and Duggan, 2006; Duggan and Imberman, 2009; Autor, 2011).<sup>6</sup> The endogenous disability assumption adopted in this paper is consistent with the key message of this literature. The second strand of literature evaluates the long-term effects of the ACA (Jung and Tran, 2011; Janicki, 2012; Feng and He, 2013; Aizawa and Fang, 2013; Tsujiyama, 2013; Pashchenko and Porapakarm, 2013). This paper contributes to this literature by considering a dynamic interaction between extending health insurance coverage and the demand for federal disability insurance. The third strand of literature directly studies the interaction between health insurance and disability insurance (Gruber, 2008; Maestas et al., 2012; Kitao, 2013). My work advances this literature and evaluates the long-term effects of the ACA on federal disability insurance programs. The fourth strand of literature uses natural experiments to identify a causal relationship between health insurance coverage and health outcomes (Newhouse and Rand Corporation, 1993; Courtemanche and Zapata, 2012; Finkelstein et al., 2012; Baicker et al., 2013). Evidence found in these studies is supportive of this paper’s main mechanism: the ACA improves health outcomes and reduces the demand for federal disability insurance. The last strand of the literature is the emerging macro-health papers that endogenize medical expenditures and health accumulation (Murphy and Topel, 2006; Suen, 2006; Hall and Jones, 2007; Yogo, 2012; Halliday et al., 2012; Zhao, 2012; Ales et al., 2012; Córdoba and Ripoll, 2013). My work contributes to this literature by proposing a better estimate

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<sup>6</sup>This literature argues that after the legislative change the status of receiving disability benefits becomes an endogenous choice: conditional on having some health problems, people with bad economic alternatives (low market wages) will apply for disability assistance and receive an award in most cases.

for the health production function.

The paper is organized as follows: Section 2.2 provides institutional knowledge of the two government programs; Section 2.3 introduces the model; Section 2.4 presents the specification, calibration, and evaluation; Section 2.5 implements policy experiments; Section 2.6 presents robustness checks; and Section 2.7 concludes.

## 2.2 INSTITUTIONAL KNOWLEDGE

### 2.2.1 The Affordable Care Act

The ACA is a United States federal statute signed into law by President Barack Obama on March 23, 2010. The ACA aims to increase the rate of health insurance coverage for Americans by making a number of legislative changes. The three main components of the reform are Medicaid expansion, insurance subsidies, and an individual mandate. The reform also incorporates other components, such as imposing an employer mandate, introducing community rating, limiting profits of private health insurance companies, and restructuring Medicare reimbursement.

According to the 2012 CBO estimates, net cost of the insurance coverage provision of the ACA is \$1,168 billion for the period of 2012-2022. Although the increase in spending is partially offset by the cost reduction of Medicare, the government still needs to raise taxes to balance its budget. Currently, the government raises the Medicare payroll tax on the individual side from 1.45 to 2.35 percent for wages above 200,000 dollars a year (250,000 for joint filers), places a 3.8 percent tax on net investment income for people with high gross income, imposes a 40 percent excise tax on insurance plans with high annual premiums, collects fees on imports of pharmaceutical drugs and medical devices, and levies a 10 percent sales tax on indoor tanning services.

### 2.2.2 Federal Disability Insurance

There are two types of federal disability insurance: the SSDI provides disability benefits for “insured workers” who worked long enough and paid social security taxes; the SSI is another federal program that provides assistance to people with disabilities based on their financial need. To receive disability benefits, either from the SSDI or the SSI, a person needs to be determined by the Social Security Administration that due to a medical condition that has lasted or is expected to last for at least one year or result in death, this person is unable to either do the work that one did before or to adjust to other work. The Social Security Administration uses a list of medical conditions combined with the applicant’s medical history to make a determinant. If benefits are awarded, people will receive monthly cash payments started five month after the onset of disabilities. In 2011, the average monthly benefits for newly awarded SSDI worker beneficiaries are 1,189 dollars. Besides cash benefits, beneficiaries receiving the SSDI also get Medicare after a 24 month waiting period. People deemed disabled continue to receive cash and Medicare benefits until they experience a medical recovery, pass away, or reach the Full Retirement Age. Most people on the disability rolls do not work due to the high implicit tax rate and the threat of continuing disability reviews.

Over the past four decades, the percent of U.S. residents aged 20-64 receiving the SSDI almost tripled: from 1.3 percent in 1970 to 4.5 percent in 2011. The percent of SSI recipients grew at a similar rate as the SSDI. In 2011, these two programs cost the federal government \$150 billion. Due to large benefit outlays and limited revenue from payroll taxes, the Social Security Disability Insurance Trust Fund is projected to be depleted by 2016. Economists attribute the Social Security Disability Benefits Reform Act of 1984 that liberalized the disability screening process as the main cause for the skyrocketing disability rolls ([Duggan and Imberman, 2009](#)). In 1983, beneficiaries with a main diagnosis as musculoskeletal disorders (e.g. back pain) or mental disorders constituted 29.7 percent of new awards, but in 2011 this number rose to 53.1 percent. [Autor and Duggan \(2006\)](#) argue

that in response to liberalized disability criteria, the status of receiving disability benefits becomes an endogenous choice. Conditional on having some health problems people with bad economic alternatives will apply for the benefits and receive an award in most cases.

## 2.3 MODEL

The model is designed to capture the general equilibrium effects of health care reforms. In addition to agents' behaviors, the model allows tax rates, insurance premiums, and factor prices to respond to policy reforms.

### 2.3.1 Demographics

The economy is populated by a constant size of overlapping generations. Agents live up to  $J$  periods. In the first  $Jr - 1$  periods, agents decide whether to work or claim disability benefits. From the period of  $Jr$ , all agents retire, receive retirement benefits, and Medicare coverage. Between periods, agents face an exogenous survival probability  $s(j)$ , where  $j$  is a period index.<sup>7</sup>

### 2.3.2 Individual Problem

Agents are born into different types  $z$ , and  $Pr(z)$  denotes the probability for each type. This type determines agents' initial health capital, group insurance eligibility, and labor abilities.<sup>8</sup> Labor abilities affects two aspects of lifetime opportunities: age-efficient labor

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<sup>7</sup>This paper sets survival probability as exogenous, because it focuses on behaviors of working-age agents. As shown in Figure 3 of [Halliday et al. \(2012\)](#), relaxing this assumption does not affect medical expenditures of working-age people.

<sup>8</sup>For simplicity, this paper abstracts from dynamic changes of group insurance eligibility, since this variable is very persistent in the data (Medical Expenditure Panel Survey).

profiles  $\zeta(z, j)$  and social security benefits  $b(z, j)$ . The group insurance eligibility is denoted as  $g(z)$ , which takes a value of 1 for those eligible for group insurance.

Figure 2.1: Timing of decisions

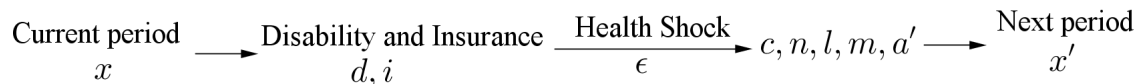


Figure 2.1 presents the timing of decisions. For each period, agents are characterized by a state vector  $x = (z, j, h, a, e)$ , where  $h$  is the current health capital,  $a$  is the amount of assets, and  $e$  represents Medicaid eligibility. Given a state vector, agents make a two-stage decision. First, they choose insurance coverage and disability status. Agents with health capital below the eligibility criterion of disability insurance ( $h < \underline{h}_d$ ) have the option to apply for disability benefits. Agents claiming disability benefits are restricted from work for one period. The disability status is denoted as  $d$ , which equals 1 if an agent receives disability assistance. Depending on eligibility an agent will enroll into an insurance plan in the order of Medicaid, Medicare, and group health insurance.<sup>9</sup> Agents lacking access to these three options are free to choose between individual health insurance and no coverage.  $i$  denotes the insurance coverage, and takes the value of 0, 1, 2, 3, and 4 to represent no insurance, group insurance, individual insurance, Medicare, and Medicaid, respectively. Following the first stage decisions, a health shock  $\epsilon$  is revealed.<sup>10</sup> The probability distribution of health shocks is denoted as  $P(\epsilon, j)$ . In the second stage, after observing the value of health shocks, agents make decisions on leisure, labor, consumption, medical expenditures, and savings. Agents' decisions are made to maximize the life-time utility flows from consumption, leisure, and health capital.

<sup>9</sup>The assumption that agents eligible for group insurance enroll into group plans is consistent with empirical evidence found in Gruber and Washington (2005) that the uninsured rate among this group is only 7 percent.

<sup>10</sup>Because upon filing an application people need to wait at least five months or as long as several years to get a disability award, the model assumes current disability status is not a function of current health shocks.

Equation (2.1) presents the production function for health. This specification is consistent with the theory of Grossman (1972a,b) that future health capital depends on current health capital and purchased medical services. This specification also incorporates the negative influence of health shocks, which functions like a random depreciation component as discussed in Grossman (2000).

$$h' = (1 - \delta)h - \delta_\epsilon + \omega_1(j)m^{\omega_2} \quad (2.1)$$

where  $\delta$  is a depreciation rate,  $\delta_\epsilon$  represents the additional depreciation caused by a health shock  $\epsilon$ ,  $\omega_1(j)$  and  $\omega_2$  are the parameters governing the process of transforming medical expenditures into health capital.

Given prices and taxes, the individual dynamic problem solved by an individual of age  $j = 1, \dots, Jr - 1$  can be written as follows.<sup>11</sup>

$$V(x) = \max_{d,i} E_{\epsilon|j} \left\{ \max_{c,n,l,m,a' \geq 0} u(c, l, h) + \beta s(j) E_{\epsilon'|x,n} V(x') \right\} \quad (2.2)$$

$$s.t. \quad c + a' + Q(m, i, j) \leq (1 - \tau)w\zeta(z, j)n\mathcal{I}_{d=0} + b(z, j)\mathcal{I}_{d=1} + (1 + r)a + Tr \quad (2.3)$$

$$n + l + st(h) \leq 1 \quad (2.4)$$

$$h' = (1 - \delta)h - \delta_\epsilon + \omega_1(j)m^{\omega_2} \quad (2.5)$$

$$i \in \begin{cases} \{4\} & \text{if } e = 1 \\ \{3\} & \text{if } e = 0, d = 1 \\ \{1\} & \text{if } e = 0, d = 0, g(z) = 1 \\ \{0, 2\} & \text{otherwise} \end{cases} \quad (2.6)$$

$$d \in \begin{cases} \{0, 1\} & \text{if } h < \underline{h}_d \\ \{0\} & \text{otherwise} \end{cases} \quad (2.7)$$

where  $V(x)$  denotes the value function, and  $\beta$  is a discount factor. Condition (2.3) corresponds to an individual budget constraint, where  $w$  is a wage rate,  $\tau$  is the payroll tax rate,  $r$  is an interest rate,  $Tr$  is a lump sum transfer redistributing the savings of deceased

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<sup>11</sup>The dynamics of Medicaid eligibility is discussed in section 2.3.3

agents equally to all alive agents,  $Q(m, i, j)$  is health related expenditures, and  $\mathcal{I}$  is an indicator function that takes the value of 1 if the subscript condition is true.<sup>12</sup> Condition (2.4) corresponds to a time constraint. Differed from the literature, the model incorporates an additional term sick time  $st(h)$  to represent the lost time of being sick. After deducting the sick time, agents are able to allocate the residual time between leisure  $l$  and labor  $n$ . Equation (2.5) is the health production function. Conditions (2.6) and (2.7) summarize the choice sets of insurance and disability decisions.

The recursive problem makes clear that agents want to invest in health for three reasons. First, agents derive utility flows from health. Second, larger health capital reduces the amount of sick time and allows agents to enjoy extra leisure and supply more labor. Third, current period's health capital composes a part of next period's health capital, and thereby there is a continuation value of good health.

### 2.3.3 Government

The government operates public health insurance programs and social security programs, including both retirement and disability programs. Public health insurance programs have two components: Medicaid and Medicare. Medicaid provides health insurance coverage for agents with income less than an income threshold  $pov$  (hereinafter referred to as an income restriction) and ineligible for neither Medicare nor group insurance (hereinafter referred to as an insurance restriction). The Medicaid contract is characterized by a coinsurance rate  $\gamma_{caid}$ , zero premiums. Prior to the ACA, besides income and insurance restrictions, agents also need to satisfy a categorical restriction to be eligible for Medicaid coverage, and the model denotes the chance of meeting the categorical restriction for each period as  $\pi$ . Medicare coverage serves as an in-kind benefits for agents with social security payments, and the Medicare contract is characterized by a coinsurance rate  $\gamma_{care}$  and premiums  $P_{care}$ . The government maintains a balanced budget and sets a flat rate tax  $\tau$  on labor income

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<sup>12</sup>More details about function  $Q(m, i, j)$  are available in Section 2.3.4



to pay for government expenditures.

### 2.3.4 Insurance Firm

A representative insurance firm offers two types of insurance contracts, group insurance and individual insurance contracts, in a competitive market. The group insurance contract is characterized by a coinsurance rate  $\gamma_1$  and premiums  $P_1$ . The individual insurance contract is characterized by a coinsurance rate  $\gamma_2$  and age specific premiums  $P_2(j)$ . Insurance premiums are picked by the insurance firm to maximize profits. Group and individual insurance markets are separated and there is no cross-subsidization between these two markets.

Given insurance characteristics, health related expenditures  $Q(m, i, j)$ , including both insurance premiums and out-of-pocket payments, can be formally expressed as follows.

$$Q(m, i, j) = \begin{cases} m & \text{if } i = 0 \\ P_1 + \gamma_1 m & \text{if } i = 1 \\ P_2(j) + \gamma_2 m & \text{if } i = 2 \\ P_{care} + \gamma_{care} m & \text{if } i = 3 \\ \gamma_{caid} m & \text{if } i = 4 \end{cases} \quad (2.8)$$

### 2.3.5 Production Firm

A representative production firm uses capital  $K$  and labor  $L$  to produce one type of final goods. Given rental prices  $\{R, w\}$  for capital and labor, the firm chooses the amount of two production factors to maximize profits.

$$\max_{K, L} AK^\alpha L^{1-\alpha} - RK - wL \quad (2.9)$$

where  $A$  is total factor productivity, and  $\alpha$  is the output elasticity of capital. Capital depreciates at a constant rate of  $\delta_k$  each period, and such that the interest rate  $r$  is equal to  $R - \delta_k$ .

### 2.3.6 Stationary Competitive Equilibrium

Let  $z \in \mathbf{Z} \subseteq \mathbf{N}_+$ ,  $h \in \mathbf{H} \subseteq \mathbf{R}_+$ ,  $a \in \mathbf{R}_+$ ,  $j \in \mathbf{J} = \{1, 2, \dots, J\}$ ,  $e \in \mathbf{E} = \{0, 1\}$ ,  $d \in \mathbf{D} = \{0, 1\}$ ,  $i \in \mathbf{I} = \{0, 1, 2, 3, 4\}$ , and  $\epsilon \in \mathbf{\Upsilon} \subseteq \mathbf{N}_+$ . Let  $\mathbf{S} = \mathbf{Z} \times \mathbf{H} \times \mathbf{R}_+ \times \mathbf{J} \times \mathbf{E}$ . Let  $\mathbf{B}(\cdot)$  be a Borel  $\sigma$ -algebra and  $\mathbf{P}(\cdot)$  be a power set. Let  $\mathfrak{S} = \mathbf{P}(\mathbf{Z}) \times \mathbf{B}(\mathbf{H}) \times \mathbf{B}(\mathbf{R}_+) \times \mathbf{P}(\mathbf{J}) \times \mathbf{P}(\mathbf{E})$ . Let  $\mathbf{M}$  be the set of all finite measures over the measurable space  $(\mathbf{S}, \mathfrak{S})$ .

**Definition** A stationary competitive equilibrium is a collection of factor prices  $\{r, R, w\}$ , production plans  $\{L, K\}$ , insurance contracts  $\{P_1, P_2(j), \gamma_1, \gamma_2\}$ , government policy  $\{\tau, b(z), P_{care}, \gamma_{caid}, \gamma_{care}, h_d\}$ , a lump-sum transfer  $Tr$ , policy functions  $d, i : \mathbf{S} \rightarrow \mathbf{D}, \mathbf{I}$ ,  $c, l, n, m, a' : \mathbf{S} \times \mathbf{D} \times \mathbf{I} \times \mathbf{\Upsilon} \rightarrow \mathbf{R}_+$ , and measures  $\Phi \in \mathbf{M}$  such that the following conditions hold.

1. Given prices, government policy, insurance contracts and the lump-sum transfer, individual decisions solve the recursive problem.
2. Aggregate quantities are consistent with individual decisions.
3. Given prices, the representative production firm makes optimal decisions.
4. The representative insurance firm earns zero profits in both group and individual insurance markets.
5. The government budget is balanced.
6. Total transfers equal the assets of deceased agents.
7. All markets clear.
8. The distribution of agents is stationary.

## 2.4 SPECIFICATION, CALIBRATION, AND EVALUATION

This paper sets the benchmark economy to match the 2006 US economy and uses three sources to collect the data information: the Medical Expenditure Panel Survey Panel

10 (MEPS), the 2007 March Current Population Survey (CPS), and the 2007 American Community Survey (ACS). The MEPS Panel 10 is a two-year panel survey with individual records on demographic features, health conditions, medical diagnoses, and medical costs. As a supplement to the MEPS, I use the CPS to collect health insurance statistics and the ACS to collect statistics about labor markets and social security programs. This section focuses on explaining the specification and calibration of several important parameters, and a complete list of parameters is provided in Table 2.1, Table 2.2, and Figure 2.2.

### 2.4.1 Demographics

One period in the model is defined as five years. People enter the economy at age 25, retire at age 65, and definitely exit at age 95. This age structure corresponds to set  $Jr$  and  $J$  to 9 and 14, respectively. Survival rates between periods are set to match the 2006 US life table (Figure 2.2 Panel A).

### 2.4.2 Individual Types

Individual types  $z$  correspond that people enter the economy with different group insurance eligibility and educational levels (high school dropouts, high school graduates, some college, and college graduates). The chance of being eligible for group insurance is estimated for each educational level as the share of people that answered yes to the question “Health Insurance Offered” in any of the five rounds of the MEPS. Multiplying these numbers with the share of adults in each educational level gives the distribution of types  $Pr(z)$ . The amount of social security entitlements  $b(z, j)$  is set to average benefits reported in the ACS. Age-efficient labor profiles  $\zeta(z, j)$  are set to the product of hourly wages of full-time-full-year workers and the time endowment, which is a standard value of 5200 hours per year (Ales et al., 2012).

Figure 2.2: Features of the 2006 US economy

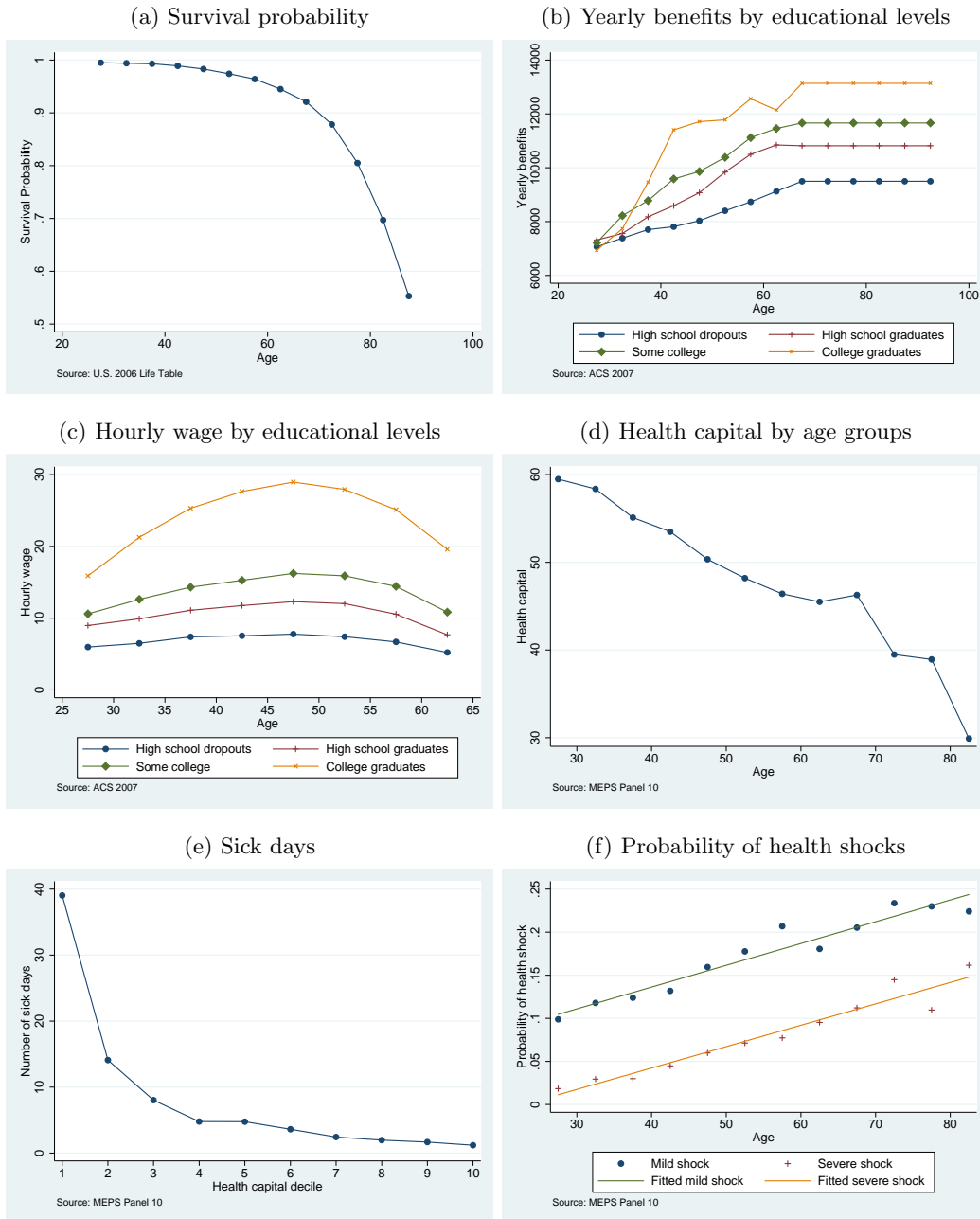


Table 2.1: A-Priori parameters

Para.	Meaning	Value	Notes
Demographics			
$Jr$	Retirement period	9	Retirement age of 65
$J$	Maximum period	14	Maximum age of 94
$s(j)$	Survival probability	Fig. 2.2 Panel A	2006 US life table
Firm production			
$\alpha$	Share of physical capital	0.33	Standard value
$\delta_k$	Depreciation of physical capital	0.40	Per-year rate of 8 percent
$A$	Productivity	1.55	Benchmark economy's wage of 1
Health insurance market			
$\gamma_1$	Coinsurance rate of group insurance	0.27	MEPS Panel 10
$\gamma_2$	Coinsurance rate of individual insurance	0.47	MEPS Panel 10
Government			
$b(z, j)$	social security benefits	Fig. 2.2 Panel B	2007 ACS
$\gamma_{care}$	Coinsurance rate of Medicare	0.25	MEPS Panel 10
$\gamma_{caid}$	Coinsurance rate of Medicaid	0.11	MEPS Panel 10
$P_{care}$	Annual Medicare premiums	1446	Sum of Part B and Part D premiums
$\pi$	Chance of Medicaid coverage	0.27	2007 March CPS
Individual problem			
$Pr(z)$	Distribution of types	Section 2.4	2007 ACS
$\zeta(z, j)$	Age-Efficiency labor profiles	Fig. 2.2 Panel C	2007 ACS
$st(h)$	Sick time	Fig. 2.2 Panel E	MEPS Panel 10
$P(\epsilon, j)$	Probability of health shocks	Fig. 2.2 Panel F	MEPS Panel 10
$\delta$	Health capital depreciation	Table 2.3	Estimates
$\delta_\epsilon$	Impact of health shocks	Table 2.3	Estimates
$\omega_1(j)$	Effectiveness parameter	Table 2.3	Estimates
$\omega_2$	Curvature parameter	Table 2.3	Estimates
$\psi$	Elasticity parameter	-0.67	Yogo (2012)
$\sigma$	Relative risk aversion	2	Standard value

Table 2.2: Calibrated parameters

Para.	Value	Target	Data	Model
$\beta$	0.921	$K/GDP$ (annual)	3.000	2.994
$\rho$	0.352	Share of working time	0.384	0.386
$\lambda$	0.921	Ratio of health capital for age groups 65-69 to 25-29	0.778	0.776
$\underline{h}_d$	29.385	Disability rate	0.058	0.057
$pov$	\$26,000	Fraction below 133% of the poverty line	0.129	0.130

### 2.4.3 Health Capital

Most papers in the literature uses subjective health status as the measure for health capital, but the reference point for subjective health status changes substantially over the life cycle. For example, the excellent condition at age 65 is not comparable to the excellent condition at age 25. In order to avoid this problem, this paper constructs an alternative measure of health capital based on the responses to a set of relatively objective questions, the Short-Form 12 (Ware et al., 1996). Based on the responses to these 12 short questions, the MEPS forms two summary scores: physical component summary (PCS) and mental component summary (MCS). These two summary scores are normalized measures with a mean of 50 and a standard deviation of 10. The health capital measure is constructed by summing up these two scores and then transforming the sum into a percentile score. In the new scale, if an agent has the health capital of 50, it indicates her health conditions are better than 50 percent of the 2006 US population. Figure 2.2 displays the life-cycle change of health capital: from 59.5 for the youngest age group to 29.9 for the oldest age group.

The constructed measure of health capital is used to specify several parameters. First, the initial endowment of health capital is measured for each educational level as the average health capital among MEPS respondents aged 25 and 29. Second, the sick time

$st(h)$  is estimated in a nonparametric way by calculating the sum of sick days missing from work and lying in bed for each decile of the health capital distribution. Estimated results indicate that the sick time declines quickly as health improves: from 39 days per year among the lowest health decile to 1 day per year among the highest health decile. Third, health measures are used to estimate the health production function. Despite the fact that this function was first introduced in 1972, only a few studies ([Grossman, 1972a](#); [Stratmann, 1999](#)) estimated it. None of the previous studies uses objective health measures and allows for random depreciation. Thus, most papers with endogenous health accumulation assume that the changes in health capital reflect the underlying health shocks and calibrate the rest parameters of health production function to match life-cycle profiles of medical expenditures. This approach underestimates the variance of health shocks, because the actual change of health capital reflects the compound effects of health shocks and purchased medical services. As a result, most calibrated models fail to produce a long tail in the distribution of medical expenditures, i.e., there is a small probability of incurring a catastrophic health shock and very large medical expenditures. To overcome this common problem, this paper directly estimates the health production function from the MEPS, which contains information about health capital of wave 2 and wave 4 (a one year span), yearly medical expenditures, and the incidence of priority conditions for each wave.<sup>13</sup> The reported incidence is interpreted as an indicator for health shocks, which is assumed to take three values: 0 for no shock, 1 for a mild shock, and 2 for a severe shock. A mild health shock is defined as having one new priority condition in either wave 3 or wave 4, and a severe health shock is defined as having multiple new priority conditions. The probability of mild and severe health shocks is estimated for each age group as the share of people reporting one and multiple new priority conditions, respectively. Because

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<sup>13</sup>Priority conditions refer to a group of medical conditions that are selected by the Agency for HealthCare Research and Quality for their prevalence, expense, or relevance to policy. Priority conditions include hypertension, heart disease, high cholesterol, emphysema, chronic bronchitis, diabetes, cancer, arthritis, asthma, attention deficit/hyperactivity disorder (ADHD or ADD), and stroke. The incidence of priority conditions is reported in medical condition files of the MEPS.

the sample does not include adults older than 85 years old, the model uses linear fitted values to construct their probabilities (Figure 2.2 Panel F). Equation (2.10) specifies the regression equation, in which the coefficient of medical expenditures is restricted to change linearly with respect to age.

$$h'_i = (1 - \delta)h_i - \sum_{q \in \{1,2\}} \delta_q \mathcal{I}_{\epsilon_i=q} + (\omega_{11} + \omega_{12}(j_i - 1))m_i^{\omega_2} + \varsigma_i \quad (2.10)$$

where  $h'_i$  is the future health capital for individual  $i$ ,  $h_i$  is the current health capital,  $\epsilon_i$  is a health shock indicator,  $j_i$  represents the period number,  $m_i$  is the total medical expenditures, and  $\varsigma_i$  is a random disturbance term capturing all omitted influences.

An OLS regression returns negative coefficients of medical expenditures, which indicates medical expenditures are an endogenous variable that people with poor unobserved health conditions tend to spend more on medical services and have worse health outcomes. To overcome the endogeneity issue, parameters are estimated using a two-stage GMM, in which medical expenditures are instrumented by family poverty status and health insurance coverage.<sup>14</sup> This instrument strategy is similar to that used by Grossman (1972a, 2000).

Table 2.3: Estimates of the health production function

$(1 - \delta)$	$\delta_1$	$\delta_2$	$\omega_{11}$	$\omega_{12}$	$\omega_2$
0.727	6.988	12.743	8.403	-0.442	0.128
(0.015)	(0.783)	(1.361)	(3.010)	(0.123)	(0.047)

Standard errors in parentheses; number of observations is 5837

As Table 2.3 reports, all estimated coefficients of the health production function are significant at the 0.01 level. Results imply that health capital depreciates over time. The incidence of health shocks reduces agents' health capital. The negative impact caused by

<sup>14</sup>Due to the limited variation of instruments after retirement, the sample is restricted to working-age people.



a severe shock is larger than a mild shock. Medical expenditures help to improve health capital, but the effectiveness of medical expenditures declines quickly as people age. The curvature parameter  $\omega_2$  of 0.128 reflects that health capital is produced via a decreasing return to scale technology. This point estimate is within the range of estimates 0.098-0.170 in [Grossman \(1972a\)](#) and consistent with the theory of [Ehrlich and Chuma \(1990\)](#).

#### 2.4.4 Preferences

The utility function is specified in the following form.

$$u(c, l, h) = \frac{[\lambda(c^\rho l^{1-\rho})^\psi + (1 - \lambda)h^\psi]^{\frac{1-\sigma}{\psi}}}{1 - \sigma} \quad (2.11)$$

where  $\sigma$  is the relative risk aversion,  $\psi$  captures the elasticity of substitution between the consumption-leisure combination and health capital,  $\lambda$  is a weight attached to the consumption-leisure combination, and  $\rho$  is the share of consumption in the consumption-leisure combination. In terms of values,  $\sigma$  is set to 2, and  $\psi$  is set to -0.67 to match the elasticity estimate of 0.6 in [Yogo \(2012\)](#). The rest parameters of the utility function are calibrated to match data moments.  $\lambda$  is calibrated to match the decline of health capital over the life cycle, specifically, the ratio of average health capital of the age group 65-69 to the age group 25-29, that is 0.78.  $\rho$  is calibrated to match the share of time spent on work among workers, that is 0.38. The discount factor between periods is set to match the ratio of capital to yearly GDP, that is 3.<sup>15</sup>

#### 2.4.5 Health Insurance Market

Coinurance rates of group and individual health insurance are estimated for each insurance type as the medium ratio of out-of-pocket payments to total medical expenditures. This number is 0.27 for group insurance and 0.47 for individual insurance. The model

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<sup>15</sup>The algorithm for solving a competitive equilibrium is available in [Appendix A.1](#).

assumes that individual premiums change linearly respect to age and the premiums paid by people aged 60-64 are three times as much as the premiums paid by people aged 25-29.<sup>16</sup> Insurance premiums are determined endogenously by solving the insurance firm's zero-profit conditions.

#### 2.4.6 Government

The disability cutoff point  $\underline{h}_d$  is calibrated to match the share of working-age people receiving disability benefits, that is 5.8 percent (the 2006 Annual Statistical Report on the Social Security Disability Insurance Program). The coinsurance rates are measured for each insurance type as the medium ratio of out-of-pocket payments to total medical expenditures. This number is 0.25 for Medicare and 0.11 for Medicaid. Medicare premiums are set to the sum of Part B and Part D premiums in 2006, which is \$1,446 per year. The Medicaid income threshold  $pov$  is calibrated to match the fraction of working-age-non-disabled adults with income below 133 percent of the poverty line, which is 12.9 percent. The probability  $\pi$  of obtaining Medicaid coverage conditional on satisfying income and insurance restrictions is set to 0.27 as in the CPS. The payroll tax rate is solved endogenously from the government budget constraint.

#### 2.4.7 Evaluation of the Model

To evaluate the model, Table 2.4 compares the moments observed in the data with those generated by the model along several important dimensions that are not targeted. First, the model reproduces the decline of health capital after retirement: in the model, average health capital of the age group 80-84 is 57.6 percent of that of the age group 25-29, which is very close to the data number of 52.3 percent. The model is capable of generating this

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<sup>16</sup>This paper uses a number of 3, because this is the ACA imposed limit, and this ratio is also close to the actual ratio before the ACA (See <http://www.healthpocket.com/healthcare-research/infostat/age-gap-bigger-than-gender-gap-for-health-insurance-premiums#.UdtLg7WyB8k>).

decline because the model allows the probability of getting health shocks to increase and the effectiveness of medical expenditures to decline with respect to age.

Table 2.4: Aggregate features: model versus data

Variables (percent)	Model	Data
Panel A: health statistics		
Ratio of health capital for age groups 80-84 to 25-29	57.6	52.3
Medical expenditures/GDP	10.9	15.4
Panel B: insurance coverage <sup>†</sup>		
Uninsured	18.1	18.0
Privately insured	74.5	72.2
Publicly insured	7.4	9.9
Panel C: disability rate <sup>†</sup>		
High school dropouts	17.3	13.7
High school graduates	8.3	7.2
Some college	2.4	4.8
College graduates	0.0	1.8

<sup>†</sup> indicates statistics among working-age people

Second, the model does not target the fraction of output used in health care sector. The model predicts people spend 10.9 percent of output on medical expenditures.<sup>17</sup> This number is smaller than the data counterpart, because the model is set to match the MEPS expenditure moments which do not incorporate the demand for expensive end-of-life care from very old people.

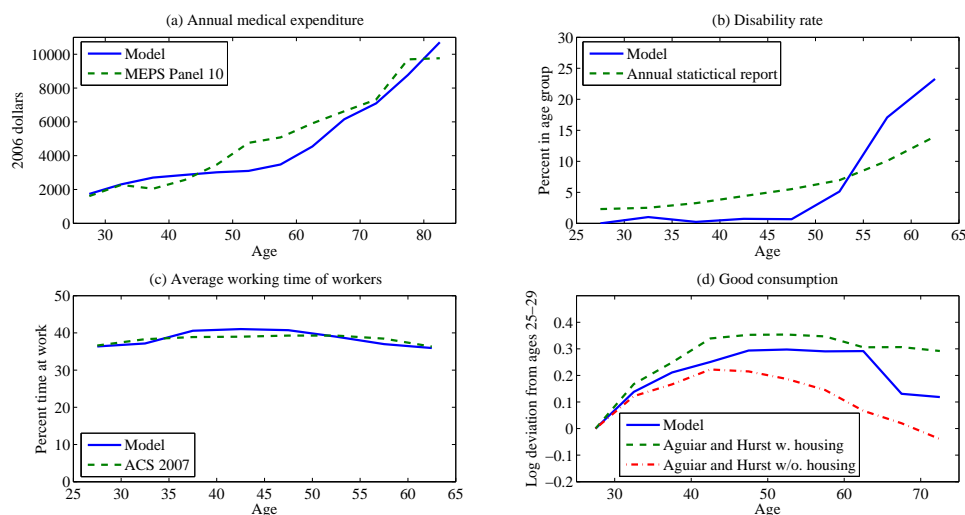
Third, the model closely matches the distribution of health insurance coverage among

<sup>17</sup>Data numbers are constructed from the 2006 National Health Expenditure Data reported by the Centers for Medicare & Medicaid Services. The amount of medical expenditures is the total expenditures of the health care sector deducting nursing home expenditures and administration costs, since these two components are not included in the MEPS.

non-retirees. As Panel B of Table 2.4 shows, the model produces an uninsured rate of 18.1 percent, which is almost the same as the data counterpart of 18.0 percent calculated from the CPS. Both in the model and in the data, private health insurance provides coverage to a much larger fraction of working-age adults than public health insurance: 74.5 percent versus 7.4 percent in the model, and 72.2 percent versus 9.9 percent in the data.

Fourth, the model correctly predicts changes of disability rates across educational levels and age groups (Panel C of Table 2.4 and Panel D of Figure 2.3). Consistent with the data, the model predicts that people with higher educational attainments are less likely to receive disability benefits. This is because the opportunity cost of becoming disabled in terms of market wages is higher for people with better education. Moreover better educated people are more likely to be eligible for group insurance, and thereby achieve good health outcomes and stay out of the disability rolls. Further, due to the generated decreasing profile of health capital, the model also captures the data fact that disability rates increase with respect to age.

Figure 2.3: Life-cycle features: model versus data



Fifth, the model fairly well matches the empirically observed life-cycle profiles of medical

expenditures, working time, and consumption. As Panel A of Figure 2.3 displays, the model correctly predicts that the amount of annual medical expenditures is around \$2,000 for the age group 25-29 and increases to \$10,000 for the age group 80-84. Besides matching the two end points, the model also captures the gradual increase of medical expenditures over the life cycle. Panel C of Figure 2.3 compares the percent of time allocated to work among workers generated by the model and that in the data. The model successfully replicates labor supply features of the data because it uses a hump-shaped age-efficient labor profile. The model also produces a hump-shaped good consumption profile (Figure 2.3 Panel D) similar to the reported profiles in Aguiar and Hurst (2013). The borrowing constraint and the precautionary saving motive for health shocks push up the consumption profile for the youth. After accumulating enough assets, middle-age agents are able to enjoy an almost constant consumption flow. Passing the retirement age, as agents have more leisure, average consumption drops.

Last, it is well known that a standard model with endogenous health accumulation can hardly generate the distribution of medical expenditures observed in the data, which is to produce a small fraction of people incurring large medical expenditures. Table 2.5 compares the distribution of medical expenditures observed in the data with the ones generated by the model. In terms of total medical expenditures, the model closely matches the average number even if this moment is not targeted. The model correctly predicts that the bottom 60 percent of people spend very little on medical services, and as people move to the right tail of the distribution their medical expenditures increase substantially. The top 5 percent of people in the model on average spend \$20 thousand per year on medical services, which is close to the data number of \$33 thousand. Besides matching the distribution of total medical expenditures, the model also matches well the distribution of out-of-pocket medical expenditures, especially the right tail of the distribution. The model is able to produce the long tail in both distributions because it incorporates a better specification for health production function and allows health capital to be a complementary good to consumption

Table 2.5: Distribution of medical expenditures: model versus data

Panel A: Distribution of total medical expenditures					
	Average	0-60%	60-80%	80-95%	95-100%
	(1)	(2)	(3)	(4)	(5)
Data	4,244	757	3,721	9,300	33,039
Model	4,282	2,004	4,694	7,490	20,415

Panel B: Distribution of out-of-pocket medical expenditures					
	Average	0-60%	60-80%	80-95%	95-100%
	(1)	(2)	(3)	(4)	(5)
Data	824	186	845	1,836	5,358
Model	1,191	625	1,277	2,006	5,228

The sample includes people aged 25-84; all numbers are in 2006 dollars

and leisure.

## 2.5 POLICY EXPERIMENTS

This section implements policy experiments to study the steady state effects of two different health care reforms: the ACA and an alternative plan without Medicaid expansion. In order to determine the importance of the disability dimension, this section also compares the results of the baseline model versus an alternative model without federal disability insurance programs.

### 2.5.1 The ACA

The evaluation of the ACA is based on studying the joint effects of its three main components: Medicaid expansion, insurance subsidies, and the individual mandate. Medicaid expansion is equivalent to remove the categorical requirement and set  $\pi$  to 1. Insurance premium subsidies are provided to people lacking access to either group insurance or Medicare. The subsidy rate declines as income rises, and the subsidy rate is zero for people with income above 400 percent of the poverty line. Table 2.6 reports subsidy rates by income brackets. The cutoff points of income levels are computed in the benchmark economy to match the fraction of working-age-non-disabled adults in corresponding income brackets in the ACS. The individual mandate is interpreted as a new 2.5 percent income tax for lacking health insurance coverage. In the new steady state, the government also runs a balanced budget and adjusts payroll taxes to fund the additional government expenditures.

Table 2.6: Income levels and insurance subsidies

Income in percent of FPL	Premium subsidy rate (CBO 2009 estimates)	Population share (Benchmark economy)
0-150	94%	15.4%
151-200	77%	7.3%
201-250	62%	8.1%
251-300	42%	7.8%
301-350	25%	7.2%
350-400	13%	6.9%

Columns 1 and 2 of Table 2.7 report summary statistics of the benchmark economy and the new steady state after the ACA. The ACA's implementation reduces the uninsured rate from 18.1 to 0.1 percent. The increased individual insurance coverage accounts for two thirds of the decline, and the increased Medicaid coverage explains the other one third. As more people obtain health insurance coverage, the fraction of GDP spent on medical expenditures increases by 4.0 percent, and the average health of working-age population rises by 2.1 percent.

Several factors affect people's demand for disability insurance. On the favorable side,

the extension of health insurance coverage can crowd out the demand for disability insurance by improving people’s health capital and reducing the relative attractiveness of the in-kind Medicare benefits, which are part of the federal disability assistance. On the adverse side, the ACA may push up the demand for disability insurance through its general equilibrium effects on wages and tax rates. Overall, the favorable effects dominate, and the disability rate drops from 5.7 to 4.9 percent.

The shrink of the disability rolls corresponds to an enlarged labor force. The model predicts that the ACA will increase the labor force participation rate by 0.9 percent. This implication is different from the recent CBO’s estimate ([CBO, 2014](#)), because the CBO does not take into account the long-term effects of the ACA on disability decisions. The prediction along the intensive margin of labor adjustments is consistent with the CBO’s estimate and the argument of [Mulligan \(2013\)](#): following the ACA people work for fewer hours per week due to the implicit high marginal tax rate created by the reform. By extending insurance coverage, the ACA also reduces the individual risk exposure to high out-of-pocket medical payments, and thereby lowers the precautionary saving motives and the capital stock of the economy. Final output will increase by 0.2 percent in the new steady state, because the adjustment of labor force participation dominates other changes.

Table [2.8](#) presents the effects of the ACA on government budget. Directly, the ACA will raise the equilibrium tax rate by 0.7 percentage point. The actual increase in taxes, however, are much smaller than the direct expenditures, because a large fraction of the ACA’s cost could be funded internally through changes of existing government programs. If normalize the ACA’s direct cost as 100 percent, the fiscal changes associated with federal disability programs will help to pay for 46.4 percent of the cost: 31.9 percent from savings of disability insurance, 7.6 percent from Medicare for people with disabilities, and 6.8 percent from revenue increase induced by larger labor supply.

To understand the welfare influence of the ACA, I compute the consumption equivalent variation (CEV) for this policy as [Conesa and Krueger \(1999a\)](#) among others. This measure



Table 2.7: Steady state comparison

	Benchmark	ACA	No Medicaid
	(1)	(2)	(3)
Uninsured rate <sup>†</sup>	18.08	0.13	0.10
Medical expenditures/GDP (%)	10.89	11.32	11.09
Average health capital <sup>†</sup>	62.96	64.26	63.97
Disability rate <sup>†</sup>	5.73	4.87	4.94
Tax rate	19.66	19.98	19.48
CEV (%)		-0.27	0.20

<sup>†</sup> indicates statistics among working-age people

Table 2.8: The effects of the ACA on government budget

	Tax rate %	Normalization
	(1)	(2)
Reform spending	0.65	100.00
Medicaid	0.59	89.95
Subsidy	0.07	10.43
Mandate	0.00	-0.38
Savings on disability assistance		
Disability insurance	0.21	31.94
Medicare	0.05	7.64
Revenue increase with a fixed tax rate		
Revenue increase	0.04	6.82

asks how much additional consumption is needed for a new born in the benchmark economy to be indifferent between living in the new economy and the benchmark economy. A positive number of CEV implies that the policy improves welfare and a negative number indicates a welfare loss. The model suggests that the ACA produces a welfare loss that is equivalent to a 0.27 percent drop of permanent consumption. This implies that gains from additional health insurance coverage do not compensate for losses from larger distortions, such as high marginal tax rates and moral hazard behaviors induced by health insurance coverage. As discussed in the following section, I find an alternative reform without Medicaid expansion reduces these distortions and creates welfare gains.

### **2.5.2 No Medicaid Expansion**

Expanding Medicaid coverage is the most controversial part of the ACA. According to the Kaiser Family Foundation, as of October 22, 2013, 26 states agreed to implement the expansion, and 25 states chose not to move forward at this time. This part aims to understand the effects of a health care reform without Medicaid expansion, under which all states choose not to move forward and impose the same Medicaid categorical restriction as the benchmark economy.

Column 3 of Table 2.7 provides summary statistics for this steady state. Relative to the ACA steady state, a reform without Medicaid expansion generates a smaller uninsured rate. This is because the margin people ineligible for Medicaid are able to purchase their coverage in the individual market. This increased participation in the individual market lowers the equilibrium premiums and thereby encourages rich people who are ineligible for insurance subsidies to purchase coverage.

Those moving from Medicaid to individual plans find the disability option to be more attractive, because compared to the ACA economy, under the new policy they need to pay a higher private price for medical services if stay in the labor market. This shift dominates the favorable effect from the reduction in equilibrium tax rates, and leads to a slightly

higher disability rate relative to the ACA economy.

Providing insurance subsidies is much cheaper than expanding Medicaid. The labor tax rate in the new steady state is 0.5 percentage point lower than the ACA economy. The difference in cost comes from the fact that a reform without Medicaid expansion greatly diminishes the number of Medicaid patients and the associated overuse of medical services. In response to the tax reduction, people in this economy are also able to produce more goods.

The policy without Medicaid expansion produces a welfare gain that is equal to a 0.2 percent increase of permanent consumption. The welfare gain is explained through two channels: the direct benefits of additional health insurance coverage and the indirect benefits of reduced tax rates. The latter channel is reflected by the observation that the equilibrium tax rate in the new steady state is 0.2 percentage point lower than the tax rate in the benchmark economy. This indicates the savings from disability insurance are larger than the cost of this particular reform, and such that a plan without Medicaid expansion not only produces gains for people participating in the individual markets but also reduces tax distortions.

### **2.5.3 No Federal Disability Insurance**

To determine the importance of the disability dimension, this section considers an alternative model, in which there is no federal disability insurance. To make the size of government comparable between two models, I add an exogenous government expenditure term equivalent in size to the spending on disability assistance of the benchmark economy of the baseline model. Parameters of the alternative model are recalibrated to match the same data moments.

Table 2.9 compares the steady state changes in response to the ACA generated by two competing models. In both models, the ACA increases labor supply and output, because extending health insurance coverage raises health capital and lowers the amount

Table 2.9: Steady state changes caused by the ACA

	w. disability	w/o. disability
	(1)	(2)
% change of labor	0.54	0.08
% change of output	0.23	0.01
$\Delta$ tax rate	0.32	0.58
CEV (%)	-0.27	-0.48

of sick time. Nonetheless, the observed increases generated by the alternative model are, respectively, 85.1 and 95.9 percent smaller than those generated by the baseline model. Moreover, an alternative model indicates that the ACA will raise the equilibrium labor tax rate by 0.58 percentage point and cause a welfare loss equivalent to a 0.48 percent reduction of permanent consumption. These two numbers are 81.3 percent larger than the corresponding numbers predicted by the baseline model. Thus, omitting changes associated with disability decisions leads to underestimates of the ACA's benefits and overestimates of the ACA's costs.

## 2.6 ROBUSTNESS CHECK

This section aims to understand whether the main mechanism of the paper—the provision of health insurance crowds out the demand for disability insurance—is robust in a variety of different assumptions. Specifically, I relax the assumption that the relative price of medical goods is constant before and after the reform. On one hand, the ACA regulates insurance contracts and encourages the use of preventative care. If this provision successfully reduces

the demand for expensive medical treatments, following the ACA, the relative price of medical goods will drop. On the other hand, as the results of [Taubman et al. \(2014\)](#) suggests, the moral hazard behaviors associated with health insurance coverage may also results in higher usage of emergency services and higher prices of medical treatments. To understand the impact on disability insurance in two scenarios, I rerun the ACA experiment by assuming different shifts of medical good prices. Surprisingly, the steady state disability rate after the ACA is almost invariant to the price shift. This is because there are two forces working in opposite directions and canceling each other out.<sup>18</sup> In summary, the proposed mechanism is robust to price shifts.

## 2.7 CONCLUSION

This paper examines the long-term effects of the ACA and considers a dynamic interaction between extending health insurance coverage and the demand for federal disability insurance programs. Results suggest that the ACA will effectively raise health insurance coverage and reduce the demand for disability insurance. The cost of larger distortions induced by the ACA, however, will outweigh the benefits obtained through disability adjustments and health insurance coverage. Thus, the implementation of the ACA will result in a long-term welfare loss. Nonetheless, I find an alternative plan without Medicaid expansion will produce similar benefits at a much cheaper cost and generate a long-term welfare gain.

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<sup>18</sup>For example, if the relative price of medical goods increases, the partial equilibrium effect indicates that people consume less medical services, have smaller health capital, and thereby be more likely to claim disability benefits; but the general equilibrium effect suggests that in response to the price change people also accumulate more precautionary savings, which raises the unit wage and the opportunity cost of claiming disability benefits. In equilibrium, these two effects cancel each other out.

### 3.0 ECONOMIC ANALYSIS OF SOCIAL SECURITY SURVIVORS BENEFITS

#### 3.1 INTRODUCTION

Survivors benefits are an important component of the social security programs. In 2011, 6.4 million Americans received survivors benefits, and the total cost was about \$106 billion.<sup>1</sup> In spite of the importance of survivors benefits, little research has been done to analyze the impacts of this particular government provision. The contribution of this paper is to provide an economic analysis about survivors benefits, particularly the survivors provision to dependent children, which has received little attention in the literature.

Survivors benefits may improve individual utility because people care about their children and spouses and want leave bequests to insure against the unfortunate event of death. The idiosyncratic mortality risks that individuals face, however, cannot be fully insured through private market transactions. Competitive markets with perfect information imply that life insurance firms charge a high price for people with larger mortality rates. Since mortality rate is negatively correlated with income ([Kitagawa and Hauser, 1973](#); [Duleep, 1986](#); [Cristia, 2007](#)), low income people need to pay a high unit price in the private market to purchase life insurance contracts. For instance, according to the estimates of [Cristia \(2007\)](#), among men aged 35-49, those from the lowest income quintile have a mortality rate 6.4 times larger than that of the highest income quintile. The provision of survivors

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<sup>1</sup>More details about social security survivors benefits are available in Section [3.2](#).

benefits compensates for the price variation in the private life insurance market and redistributes resources from people with high earnings to those with low earnings. As a result, survivors benefits help mitigate the inequality induced by the heterogeneity of mortality rates, the effects of which are amplified by the competitive life insurance market. Another gain is that survivors benefits provide insurance for income shocks and life event changes, e.g. child birth and marriage. In terms of cost, the provision of survivors benefits results in larger taxes that distort individual decisions. The second contribution of this work is to introduce the assumption of income differentiated mortality rates into macroeconomic models and study its implications in the context of policy evaluation.

In order to evaluate the impacts of survivors benefit programs, this paper builds a dynamic model with heterogeneous agents who make decisions on consumption, bonds, and life insurance holdings. As in [Yaari \(1965\)](#), the demand of life insurance is derived from agents' incentives to leave a bequest. Life insurance firms perfectly observe mortality risks, and such that the unit price of insurance depends on individual mortality rates. Differed from previous macroeconomic analyses of social security programs ([Hubbard and Judd, 1987](#); [Imorohoroğlu et al., 1995](#); [Conesa and Krueger, 1999b](#); [De Nardi et al., 1999](#); [Hong and Ríos-Rull, 2007](#); [Imorohoroğlu and Kitao, 2012](#); [Hosseini, 2008](#)), this paper allows the mortality rate to depend on both age and individual average income. Specifically, consistent with empirical observations, in the model, high income agents have lower mortality rates than low income agents in an age category. The designed negative correlation between income and mortality rate is the main reason that justifies the public provision of survivors benefits.

The model is calibrated to match the 2001 US economy. In particular, I target the parameters that describe bequest functions to match the average life insurance holdings by demographic groups. The calibrated model fits the data well by matching several important moments that are not targeted, such as life-cycle changes of the average ratios of life insurance face value to earned income and the variation of life insurance holdings

across income groups and family types.

The model is used to simulate the impacts of several social security reforms. Quantitative results suggest that removing survivors benefits for dependent children generates an ex-ante utility loss equivalent to a 0.33 percent drop of permanent consumption, but removing survivors benefits for aged spouses generates an ex-ante utility gain that equals a 0.72 percent rise of permanent consumption. The implication of survivors benefits is largely affected by the specification of mortality rates. An alternative model, which adopts a standard assumption that mortality rates only depend on age, predicts that the gains associated with survivors benefits are substantially smaller. For example, the utility loss of removing survivors benefits for dependent children derived from the alternative model is 64 percent smaller than that of the baseline model.

In addition to the effects on agents, the rule changes of survivors benefits also affect the amount of bequests received by survivors. Results indicate that removing survivors benefits for dependent children lets 80.8 percent dependent children receive fewer bequests, and the average amount of bequests drops by 3.9 percent. Following the removal of survivors benefits for aged spouses, 88.8 percent of widows receive fewer bequests, and the drop in bequest amounts averages at 1.3 percent.

This paper is related to three strands of literature. The first strand of literature empirically identifies the existence of bequest motives and investigates the effects of social security programs on the life insurance demand ([Bernheim, 1991](#); [Fitzgerald, 1987](#); [Lewis, 1989](#)). Their findings provide a foundation for the two key assumptions of the model: agents value bequests and survivors benefits are a substitute to life insurance. The second strand of literature studies how life insurance and survivors benefits help smooth consumption flows between different survival states ([Auerbach and Kotlikoff, 1987, 1991](#); [Bernheim et al., 2003](#)). This paper extends this literature by simulating the impact of different policy reforms on consumption smoothing. The last strand of literature is macroeconomic papers on life insurance demand ([Fischer, 1973](#); [Chambers and Schlagenhauf, 2004](#); [Hong](#)



and Ríos-Rull, 2012; Krebs et al., 2012). Contributing to this literature, this paper considers survivors benefits for dependent children and the income differentiated mortality assumption, under which mortality rates are negatively correlated with income.

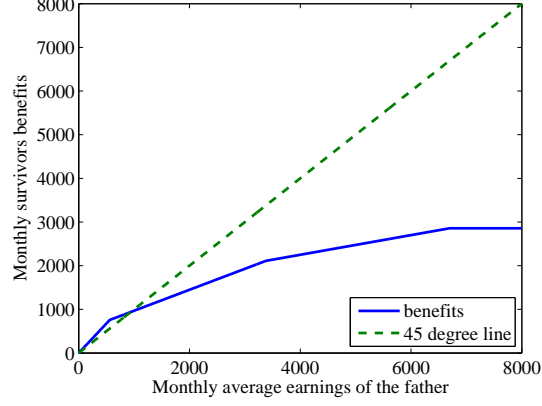
The paper is organized as follows: Section 3.2 describes social security survivors benefits; Section 3.3 presents the model; Section 3.4 describes the model’s specification, calibration, and evaluation; Section 3.5 reports policy experiments; Section 3.6 conducts robustness checks; and Section 3.7 concludes.

## 3.2 SURVIVORS BENEFITS

Survivors benefits are one important component of the social security programs. In 2011, the survivors program paid a total amount of 105.7 billion dollars to 6.4 million survivors of deceased workers. Four types of people are entitled to survivors benefits: aged or disabled widows or widowers, dependent children, widows or widowers taking care of children, and dependent parents. This paper focuses on the first two types, because these beneficiaries account for 96.4 percent of the total expenditure outlays of social security survivors benefits.

The provision of survivors benefits for aged spouses allows a widow to claim the maximum of her own retirement benefits or the retirement benefits of her deceased husband. The survivors program has an early retirement option: a widow could apply for the full amount of benefits at her normal retirement age or a reduced amount of benefits as early as she reaches 60 years old. A penalty for early claims is implemented such that the present value of social security benefits is invariant to the claiming date. The provision of survivors benefits for dependent children allows each child (under age 18) of deceased workers to receive 75 percent of the insured workers social security entitlements. Figure 3.1 displays the entitled monthly survivors benefits for two dependent children. The benefit formula implies that if the father of two children dies, survivors benefits will issue monthly

Figure 3.1: Survivors benefits for two dependent children (2001 dollars)



paychecks to the children and the paycheck amount could replace up to 135 percent of the deceased father's earnings. The abovementioned social security rules combined with family characteristics collected from the SIPP are used to construct the function that defines survivors benefits  $S^s(\bar{e}, j, f)$  in the model.<sup>2</sup>

Figure 3.2 compares life insurance holdings with the entitled survivors benefits. The comparison indicates that survivors benefits are an important source of income to protect families from the decease of workers. Especially, among young fathers and retired husband, the entitlements of survivors benefit are larger than private life insurance holdings.

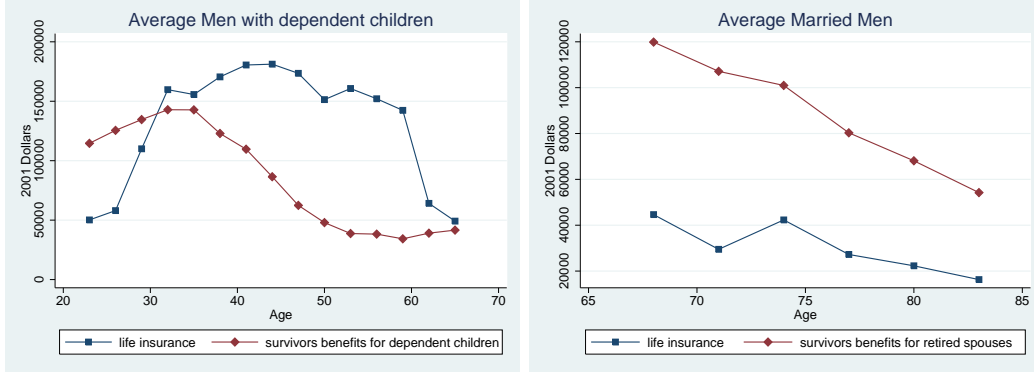
### 3.3 MODEL

This section presents a dynamic model with heterogeneous agents, who derive utility flows from consumption and bequests. In addition to agents, the economy also includes a gov-

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<sup>2</sup>Conforming to the rule of maximum family benefits, the model assumes that the maximum survivors benefits a family entitled to are the sum of benefits for two youngest children and those for an aged spouse.

Figure 3.2: Life insurance holdings and Survivors Benefits



(a) Fathers

(b) Husbands

Data source: the SIPP 2001 Panel

ernment and a representative insurance firm.

### 3.3.1 Demographics

The economy is populated by a constant size of overlapping generations. Each generation lives up to  $J$  periods. Agents work in the first  $Jr - 1$  periods and retire from period  $Jr$ . Between periods, agents face the uncertainty of survival, the probability of which is denoted as  $s(\bar{e}, j)$ , where  $j$  is an age index and  $\bar{e}$  is the average earned income up to period  $j$ . Agents also transit between different family types  $f$ , the process of which follows a finite-state Markov chain with transitions  $P(f'|f, j)$ .

### 3.3.2 Individual Problem

Agents are characterized by a state vector  $\phi = (k, \bar{e}, \eta, \iota, j, f)$ , where  $k$  represents bond holdings,  $\eta$  represents a permanent productivity component, and  $\iota$  represents a stochastic

productivity shock, which follows a finite state Markov chain with stationary transitions  $Q(\iota'|\iota)$  over time. Given a state vector, agents choose consumption  $c$ , life insurance  $x'$ , bequests  $b'$ , and bonds  $k'$  to maximize life time utility.

Given prices and taxes, the individual dynamic problem solved by an individual of age  $j = 1, \dots, J$  can be written as follows.

$$V(\phi) = \max_{c \geq 0, x' \geq 0, k' \geq 0, b' \geq 0} \{u(c) + \beta(1 - s(\bar{e}, j))v(b', j, f) + \beta s(\bar{e}, j) \sum_{f'} \sum_{\iota'} V(\phi') Q(\iota'|\iota) P(f'|f, j)\}$$

s.t.

$$c + k' + p(\bar{e}, j)x' \leq k(1 + r) + w\varepsilon(j)\eta\iota + S^r(\bar{e}) - T^{ss}(w\varepsilon(j)\eta\iota) - T(rk + w\varepsilon(j)\eta\iota + S^r(\bar{e})) \quad (3.1)$$

$$b' \leq k'(1 + r) + x' + S^s(\bar{e}, j, f) \quad (3.2)$$

where  $V(\cdot)$  is the value function, and  $\beta$  is a discount factor. The utility flows from consumption and bequests are additive and represented respectively by  $u(c)$  and  $v(b', j, f)$ . Both functions satisfy the Inada conditions. Condition (3.1) corresponds to a budget constraint, where  $p$  denotes the unit price of life insurance,  $r$  is the net return on bonds,  $w$  is the wage rate,  $\varepsilon(j)$  represents age-efficient labor profiles, and  $T^{ss}(\cdot)$ ,  $T(\cdot)$ ,  $S^r(\cdot)$ , and  $S^s(\cdot)$  denotes social security taxes, income taxes, retirement benefits, and survivors benefits, respectively. Condition (3.2) describes that bequests are consisted of three parts: gross return on bonds, life insurance holdings, and survivors benefits.

The individual problem makes clear that the average income  $\bar{e}$  affects social security entitlements and individual survival rates, which in turn determine life insurance prices. The law of motion for this variable is specified as follows.

$$\bar{e}(j) = \begin{cases} w\varepsilon(j)\eta\iota & j = 1 \\ ((j - 1)\bar{e}(j - 1) + w\varepsilon(j)\eta\iota)/j & 1 < j < Jr \\ \bar{e}(j - 1) & j \geq Jr \end{cases} \quad (3.3)$$

### 3.3.3 Government

The government operates social security programs and collects income taxes. The social security programs levy a social security tax on earned income and issue benefits to retirees and survivors. Retirement benefits  $S^r(\bar{e})$  are issued to agents older than the retirement age  $Jr$ , and survivors benefits  $S^s(\bar{e}, j, f)$  are issued as a one-time-lump-sum transfer to dependent children and aged spouses of deceased agents. The social security benefit rules imply that the amount of survivors benefits should depend on the agent's average earnings, age, and family types.

### 3.3.4 Life Insurance Firm

There is a representative life insurance firm issuing insurance contracts in a competitive market. Individual mortality rates are perfectly observed by the life insurance firm, and such that insurance contracts are sold at a unit price  $p(\bar{e}, j) = (1 - s(\bar{e}, j))/(1 + r)$ .<sup>3</sup>

## 3.4 SPECIFICATION, CALIBRATION, AND EVALUATION

The model is calibrated to match the 2001 US economy, and a full list of parameters is reported in Table 3.2. The used data moments are constructed from the male respondents in the Survey of Income and Program Participation (SIPP) 2001 Panel Wave 3.<sup>4</sup> SIPP is a panel survey that collects information for income and program participation, including economic well-being, family dynamics, education, assets, health insurance, childcare, and food security.

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<sup>3</sup>This paper assumes that there is no asymmetric information in the life insurance market, which is supported by the results of Cawley and Philipson (1999).

<sup>4</sup>This paper uses the year of 2001 because the information of individual life insurance face value is unavailable for more recent years. The data sample includes male respondents aged 22-84, but excludes working-age people without income information and retirees with dependent children. The sample contains 17,703 observations.

### 3.4.1 Demographics

One period in the model is defined as three years. Agents enter the economy at age 22, retire at age 67, and definitely exit at age 102. This age structure corresponds to set  $Jr$  to 16 and  $J$  to 27.

Survival rates  $s(\bar{e}, j)$  are specified to match two data features: this rate declines with respect to age and increases with respect to average income. Specifically, it is parameterized in the following form.

$$s(\bar{e}, j) = 1 - m_j [1 + \max\{\kappa_1 + \kappa_2(j - 1), 0\} \frac{\bar{e} - \bar{e}_j}{\bar{e}_j}]. \quad (3.4)$$

where  $m_j$  is the average mortality rate for agents of period  $j$ , which is set to match the numbers reported in the US period life table.  $\bar{e}_j$  is the average of  $\bar{e}$  for all agents in period  $j$ .  $\kappa_1$  and  $\kappa_2$  are the parameters governing the process of transforming income differences into mortality differences. These two parameters are jointly calibrated to match the mortality ratios reported in Table 3.1, and the implied values are  $\kappa_1 = -0.9280$  and  $\kappa_2 = 0.0432$ .<sup>5</sup> A negative  $\kappa_1$  indicates that agents with low average income have higher mortality rates than those with high average income in an age category. A positive  $\kappa_2$  suggests that the variation of mortality ratios declines as agents age.

Agents are assumed to transit between three family types: married with dependent children, married without dependent children, and singles. The initial distribution and the transitions of working-age agents are specified to match the distribution and transitions of family types in the SIPP.<sup>6</sup> For retirees, the model assumes the probability attached the state with dependent children is zero and the marital status remains unchanged except that the spouse may die. The transitions of family types for retirees are computed using

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<sup>5</sup>Mortality ratio for an income group in a certain age category is computed as the ratio of this income group's mortality rate relative the age category's mortality rate. Parameter values are picked to minimize the sum of squared percent deviations between data moments and model moments. The model uses 2 parameters to target 15 data moments, and on average the model moments deviate from the data moments by 18 percent.

<sup>6</sup>The SIPP is a panel survey and contains the information of family types over a three year span.

Table 3.1: Mortality ratio, male (Cristia, 2007)

Life earning quintile	Age group		
	35-49	50-64	65-75
Bottom	2.25	1.63	1.10
Second	1.13	1.10	1.14
Third	0.73	0.99	1.08
Fourth	0.56	0.68	0.94
Top	0.35	0.61	0.74

the mortality rates of a three-year-younger female, since on average the wife is three-year younger than the husband.

### 3.4.2 Labor Endowments

The permanent income component  $\eta$  is assumed to be drawn from a log-normal distribution, which is characterized by a mean of zero and a standard deviation of  $\sigma_d$ . The natural logarithm of stochastic shocks  $\ln \iota$  is assumed to follow an AR(1) process with a persistence  $\rho$  and a conditional variance  $\sigma_s^2$ , which is described in equation (3.5)

$$\ln \iota' = \rho \ln \iota + o, \quad o \sim N(0, \sigma_s^2) \quad (3.5)$$

Following the method of Conesa et al. (2009), these three parameters  $\sigma_d^2$ ,  $\rho$  and  $\sigma_s^2$  are jointly calibrated to match the increasing variances of logarithmic wages from ages 22 to 55 in the SIPP.<sup>7</sup> The calibrated values are  $\rho = 0.935$ ,  $\sigma_s = 0.205$ , and  $\sigma_d = 0.618$ . The

<sup>7</sup>Parameter values are picked to minimize the sum of squared percent deviations between model generated moments and data moments. The model uses 3 parameters to match 34 data moments, and on average the model moments deviate from the data moments by 11 percent.

age-efficient earning profile is normalized to 1 for the first period and changes over time according to the profile reported in Hansen (1993). The wage rate  $w$  is set to the average wage of the youngest age group.

Table 3.2: Parameters

Parameter	Value	Source
$Jr$	16	Retirement age of 67
$J$	27	Maximum age of 102
$m_j$		Period life table
$\kappa_1$	-0.928	Jointly calibrated to match mortality ratios
$\kappa_2$	0.043	reported in <a href="#">Cristia (2007)</a>
$\ln w$	10.911	Income at age 22
$\varepsilon(j)$		Hansen (1993)
$\sigma_d$	0.618	Jointly calibrated to match the increasing
$\rho$	0.935	variance of logarithmic wages between ages 22
$\sigma_s$	0.205	and 55
$r$	0.090	3 percent per year
$\sigma$	2.000	Standard value
$\beta$	0.917	$1/(1+r)$
$\chi_{j,f}$		Calibrated to match average insurance holdings



### 3.4.3 Preferences

Individual preferences are specified as follows

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma} \quad (3.6)$$

$$v(b, j, f) = \chi_{j,f} \frac{b^{1-\sigma}}{1-\sigma}. \quad (3.7)$$

where  $\sigma$  is the relative risk aversion parameter, which is set to 2.  $\chi_{j,f}$  represents the weight attached to bequests for an agent of period  $j$  and family type  $f$ . The model assumes that the ratios of bequest weights of married men with and without dependent children to that of single men in the same age category are invariant with respect to age. The bequest weights for singles and the two ratios are jointly calibrated to match the average life insurance holdings by three-year-age cohorts and the average difference of life insurance holdings across family types.<sup>8</sup> The calibrated weights are hump-shaped with a peak reached at retirement. For each age category, the weights for married with dependent children and married without dependent children are respectively 3.42 and 1.63 larger than singles. The net return on bonds  $r$  is set to 0.09, which corresponds to a yearly interest rate of 3 percent. The discount factor  $\beta$  is assigned to  $1/(1+r)$ .

### 3.4.4 Government

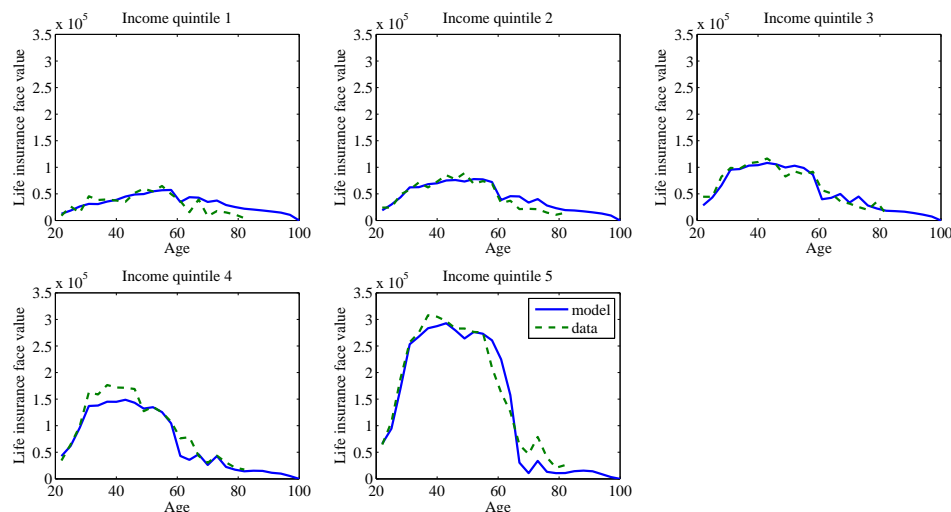
The income tax rate schedule is set to replicate the deductions and marginal tax rates of a household head in 2001. Besides income taxes, agents also need to pay a 10.6 percent flat rate tax on earned income up to a taxable maximum. The entitlements of retirement and survivors benefits are calculated based on the family characteristics of male respondents in the SIPP and the 2001 social security rules.

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<sup>8</sup>The model assumes that the weights for each family type remain unchanged from age 84, and on average the model moments miss the targets by 6.3 percent. The algorithm is reported in Appendix [A.2](#).

### 3.4.5 Evaluation

Figure 3.3: Life insurance holdings by income groups

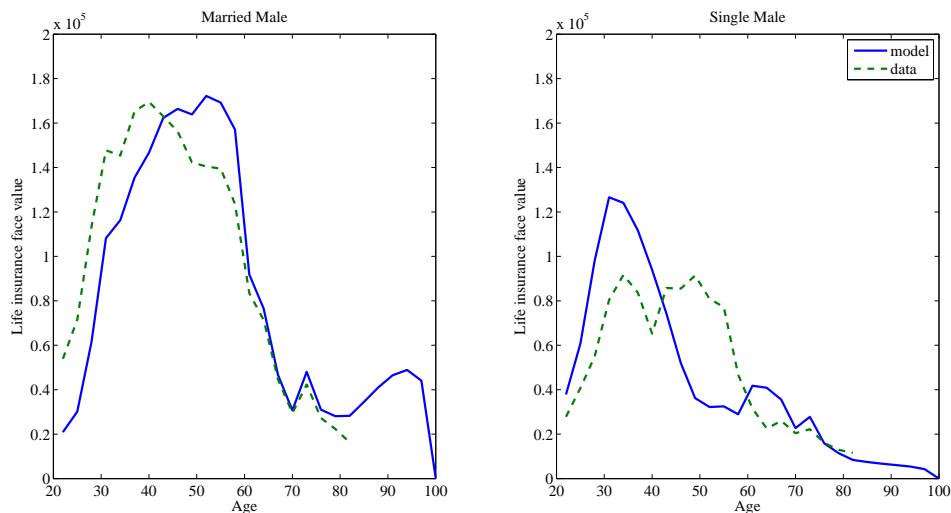


To evaluate the model, this section compares the model generated moments with the data moments along several important dimensions that are not targeted. First of all, the model closely tracks the life-cycle changes of insurance holdings by income groups (Figure 3.3).<sup>9</sup> The model successfully matches data moments because it correctly specifies the social security survivors benefits program. Survivors benefits for dependent children provide very generous deceased-contingent payments to low income fathers, and such that this program to a large degree crowds out this group's private demand for life insurance and leads to a relatively flat life-cycle profile. For the high income counterparts, survivors benefits only replace a small fraction of the forgone income and thereby upon the birth of children these high income fathers need to immediately purchase large amounts of private

<sup>9</sup>For working-age men, income includes earned income, employee compensation, and transfers from government programs. For retirees, income includes private and public pensions. Agents are grouped into different income quintiles by their positions in a three-year-age cohort. To address the issue of early retirement, from the age of 58 an individual with zero earned income are assigned to a position based on his retirement income.

life insurance, which results in an inverted U-shaped profile. Second, as Figure 3.4

Figure 3.4: Life insurance holdings by family types



displays, the model closely matches life-cycle changes of life insurance holdings by family types though it slightly overestimates the decline of life insurance holdings among single men in their late 40s. This difference between data and model could be attributed to the data imperfection that some reported singles are divorced fathers who want to hold life insurance for their children, and thereby the data number reflects the mix decisions of singles and fathers. Third, Figure 3.5 compares the life-cycle changes of average ratios of life insurance face value to earned income by income groups observed in the data with the ones generated by the model. The model is able to produce numbers close to the data, because it properly considers survivors benefits and derives the demand for life insurance. Last, as Figure 3.6 demonstrates, the model produces a life cycle profile of consumption variance similar to the reported profile in [Aguiar and Hurst \(2013\)](#).

Figure 3.5: Average ratios of life insurance to earned income by income groups

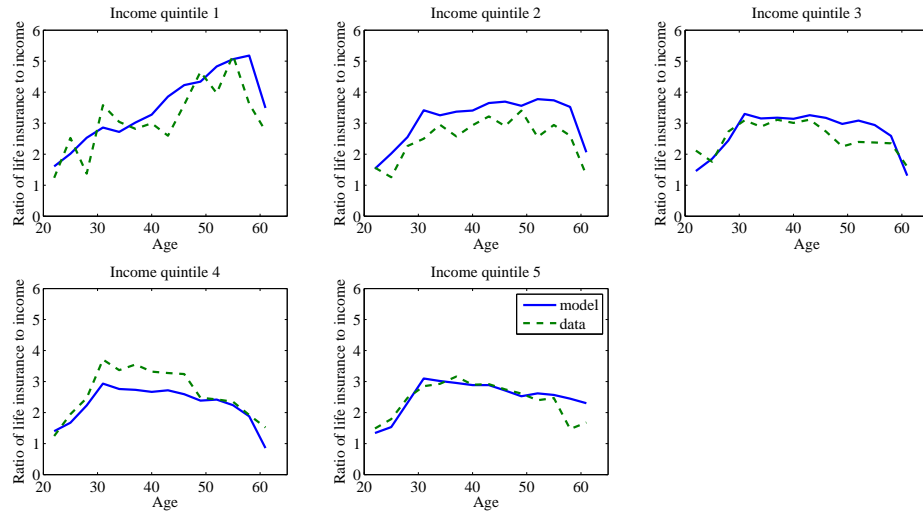
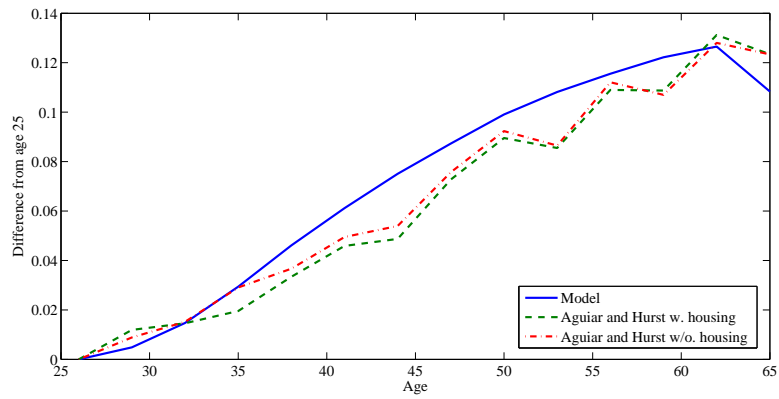


Figure 3.6: Life cycle profile of consumption variance



### 3.5 POLICY EXPERIMENTS

This section conducts policy experiments to exploit the impacts of removing survivors benefits for dependent children and survivors benefits for aged spouses separately. In order to determine the importance of the income differentiated mortality assumption, this section also compares the results of the baseline model to those of an alternative model, in which mortality rates only depend on age.

#### 3.5.1 No Survivors Benefits for Dependent Children

Table 3.3 summarizes the most important aggregate statistics of different economies, where earned income is normalized to 100. The first column corresponds to the benchmark economy, and the second column corresponds to an economy that excludes survivors benefits for dependent children. In addition to the modification of benefit rules, the social security tax rate is reduced by 0.29 percentage point in the new economy to reflect the change in the cost of providing social security programs. Compared to the benchmark economy, agents in the new economy purchase more bonds and life insurance. The life insurance face value and life insurance premiums rise by 36.3 and 12.5 percent, respectively. The change of insurance premiums is much smaller than that of the face value, because the removal of survivors benefits for dependent children mainly pushes up the demand for life insurance from young fathers who face a low price.

To understand the welfare implication of this policy, I compute the consumption equivalent variation (CEV) as Conesa and Krueger (1999b) among others. This CEV measures how much additional consumption is needed for a new born in the benchmark economy to be indifferent between living in the new economy and the benchmark economy. A positive number implies welfare gains and a negative number indicates welfare losses. The model suggests that removing survivors benefits for dependent children leads to an ex-ante utility loss equivalent to a 0.33 percent decline of permanent consumption. This finding indicates

Table 3.3: Comparison between economies

Variables	Benchmark (1)	No benefits for	
		Dependent children (2)	Aged spouses (3)
Consumption	82.5	82.5	83.3
Bonds	251.8	252.0	263.6
Life insurance	95.0	129.4	101.0
Premiums	1.9	2.2	2.7
Earned income	100.0	100.0	100.0
CEV		-0.33%	0.72%

that the provision of survivors benefits for dependent children generates utility gains: the associated benefits of insuring mortality, income, and family-type uncertainties outweigh the associated cost of tax distortions. The primary reason for utility gains is the risk spreading of income differentiated mortality rates. As Section 3.5.3 demonstrates, the utility gain from survivors benefits for dependent children will drop substantially if I replace the mortality assumption in the baseline model by a standard assumption that mortality rates only depend on age.

The removal of survivors benefits for dependent children also reduces the amount of bequests left to children. On average the amount of bequests will drop by 3.9 percent, and about 80.8 percent of dependent children will receive smaller amounts of bequests upon the death of fathers. The largest cost is borne by child survivors of young fathers. Following the policy reform, the amount of bequests left by a 26 year old father will diminish by 54.0

percent.

### 3.5.2 No Survivors Benefits for Aged Spouses

The third column of Table 3.3 summarizes the aggregate statistics for an economy that removes survivors benefits for aged spouses. In addition to the modification of benefit rules, the social security tax rates in this economy are 1.56 percentage points smaller than the benchmark economy to reflect the change in the cost of funding social security programs. This policy change yields increases of consumption, bonds, life insurance holdings, and life insurance premiums. The insurance premiums increase by a larger fraction than the insurance face value because the removal of survivors benefits for aged spouses mainly boosts up the life insurance demand from aged men who face a high price. The removal of survivors benefits for aged spouses produces an ex-ante utility gain equivalent to a 0.80 percent increase of permanent consumption. This number indicates that the benefit of providing additional insurance for the elderly does not compensate for the cost of larger tax burdens for workers. Nonetheless, removing survivors benefits for aged spouses diminishes the bequests left to widows.<sup>10</sup> On average, the bequest amount drops by 1.3 percent, and about 88.8 percent of widows lose from the policy change.

### 3.5.3 Standard Mortality Assumption

In order to understand the importance of the income differentiated mortality assumption, this section considers an alternative model that adopts a standard assumption that mortality rates only depend on age. Parameters of the alternative model are recalibrated to match the same data moments. Table 3.4 compares the consumption equivalent variations of removing survivors benefits derived by two competing models. The CEV numbers of the alternative model with standard mortality rates are larger than those of the baseline

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<sup>10</sup>Results here are consistent with the argument of [Hong and Ríos-Rull \(2012\)](#) that removing survivors benefits for aged spouses benefits male but impairs female.

model. This indicates that omitting the fact that mortality rates are negatively correlated with income leads a model to underestimate the gains produced by survivors benefits. For example, the utility loss of removing survivors benefits for dependent children derived from the alternative model is 64 percent smaller than that of the baseline model.

Table 3.4: Implications of two competing models

	Consumption equivalent variations (%)	
	Income differentiated mortality	Standard mortality
No benefits for dependent children	−0.33	−0.12
No benefits for aged spouses	0.72	0.80

### 3.6 ROBUSTNESS CHECK

This section aims to understand whether the implications about survivors benefits are robust in a variety of different assumptions. In particular, I change the relative risk aversion parameter of bequest functions. Table 3.5 compares consumption equivalent variations generated by different models. Results indicate that the implications of survivors benefits are robust to a variety of parameter choices, although agents derive larger gains from survivors benefits if bequests are less substitutable between periods.

### 3.7 CONCLUSION

Considering that mortality rates are negatively correlated with income, this paper analyzes the impacts of social security survivors benefits. Results suggest that the removal of



Table 3.5: Implications under different relative risk aversion assumptions

	Consumption equivalent variation (%)		
	2(baseline)	1.5	2.5
No benefits for dependent children	−0.33	−0.26	−0.35
No benefits for aged spouses	0.72	0.77	0.64

survivors benefits for dependent children makes both agents and dependent children lose; the removal of survivors benefits for aged spouses benefits agents but impairs widows.

## 4.0 TECHNOLOGICAL PROGRESS, IMMIGRATION, AND EDUCATIONAL CHOICES

### 4.1 INTRODUCTION

Pronounced changes in technology and immigration over the last several decades have motivated a large literature exploring the relationship between these two factors and labor market outcomes. In particular, [Heckman et al. \(1998\)](#) and [Eberhard \(2012\)](#) respectively studies the impact of skilled-biased technological progress and immigration on human capital accumulation. Previous papers, however, restrict human capital investment to be a one dimensional choice, and thereby cannot generate the large differences in earnings across a variety of college majors ([Arcidiacono et al., 2012](#)). The purpose and contribution of this paper is to develop a model characterizing the multidimensional nature of human capital investment and the associated choice of college majors.

The model consists of overlapping generations agents and a representative firm. The firm produces final goods using one type of routine tasks produced by unskilled workers and two types of non-routine tasks produced by skilled workers, i.e., quantitative and interactive tasks. Agents differ in their endowments of quantitative and interactive abilities, and college education helps transform the ability endowments into corresponding non-routine tasks. In college, agents can choose whether to specialize in a NSE major that is more effective in training quantitative tasks at the cost of training interactive tasks and a utility

loss.<sup>1</sup> The model exploits the impacts of technological progress and immigration on the demand and supply of different types of tasks and tracks the associated effects on years of education and the major of specialization.

The technological progress over the past few decades shifts the production function and yields larger demand for both non-routine tasks (relative to routine tasks) and quantitative tasks (relative to interactive tasks).<sup>2</sup> These demand shifts lead agents to be more likely to take college education and pursue an NSE major. For the same period, the US economy also experiences large influxes of both skilled immigrants and unskilled immigrants. The rising number of unskilled immigrants pushes up the relative price of non-routine tasks, and thereby induces more agents to pursue college education. The influx of skilled immigrants, on the contrary, raises the relative price of routine tasks, and thereby offsets the positive effect on college attendance induced by the influx of unskilled immigrants. Because skilled immigrants, relative to native-born workers, have imperfect language skills, they have a comparative disadvantage in performing interactive tasks and supply less interactive tasks than quantitative tasks in the labor market (Peri and Sparber, 2011). As the influx of skilled immigrants lowers the relative price of quantitative tasks, they reduce agents' incentives to pursue NSE majors.

The model is calibrated to match the 1969 US economy and used to examine the long-term effects of the changes in technology and immigration for the period of 1969-2006 on educational choices of native-born Americans. Results suggest that the compound effects of these two factors lead to increased attractiveness of both college education and NSE majors: the fraction of native workers with a college degree (hereinafter referred to as the skilled share) and the fraction of native college graduates with a NSE major (hereinafter

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<sup>1</sup>NSE majors covers biological and biomedical sciences, mathematics and statistics, physical sciences, science technologies, computer and information sciences, engineering, and engineering technologies. This utility loss is used to capture the pains suffered by a typical NSE major student to complete difficult assignments and receive low grades (Rask, 2010).

<sup>2</sup>Goldin and Katz (2007) summarize the changing demand for skilled workers who provide non-routine tasks relative to non-skilled workers who provide routine tasks. Section 4.4.1 documents the changes of demand for two types of non-routine tasks.

referred to as the NSE share) raise from 15.8 to 40.4 percent and 15.7 to 21.8 percent, respectively. The partial effects of these two factors, however, result in opposite reactions. Specifically, the influx of immigrants reduces natives' incentives to pursue college education and NSE majors.

This paper is related to three strands of literature. The first strand of literature studies the impact of skilled biased technological progress on the US economy ([Katz and Murphy, 1992](#); [Acemoglu, 2002](#); [Autor et al., 1998, 2003, 2008](#); [Acemoglu and Autor, 2012](#)). This paper contributes to this literature by documenting that the skilled biased technological progress is skewed to quantitative tasks and exploiting the implications. The second strand of literature examines the influence of immigrants ([Borjas, 2003, 2005, 2009](#); [Butcher and Card, 1991](#); [Card and DiNardo, 2000](#); [Friedberg, 2001](#); [Neymotin, 2009](#); [Peri and Sparber, 2009, 2011](#); [Lewis, 2011](#)). Different from previous studies, this work analyzes the general equilibrium impact of immigrants on native students' college major choices. The last strand of literature aims at explaining human capital accumulation decisions ([Ben-Porath, 1967](#); [Heckman et al., 1998](#); [Güvenen and Kuruscu, 2012](#); [Restuccia and Vandenbroucke, 2013](#)). This paper extends the literature by considering that human capital investment is a multidimensional choice.

The paper is organized as follows: Section [4.2](#) presents the model; Section [4.3](#) describes specification, calibration, and evaluation; Section [4.4](#) conducts policy experiments; and Section [4.5](#) concludes.

## 4.2 MODEL

The model consists of heterogeneous agents making educational choices to maximize life-time utility and a representative firm utilizing three types of labor inputs to produce one type of final goods.

### 4.2.1 Agent Problem

The economy is populated by a constant size of overlapping generations agents. Each generation lives  $J$  periods. Agents are born into different types  $z \in \mathbf{Z} = [0, 1]$ , and  $f(z)$  denotes its density function. This type determines agents' ability endowments: interactive abilities  $A^I(z)$  and quantitative abilities  $A^Q(z)$ .

Given the ability endowment and the sequence of factor prices, a type  $z$  agent born into cohort  $c$  solve the following optimization problem by choosing college attendance  $S_c$ , the major of specialization  $M_c$ , consumption  $c_{c,t}$  and asset  $a_{c,t+1}$  sequences, where  $t$  is a time index,  $S_c$  and  $M_c$  take the value of 1 for those completing college and NSE majors, respectively.

$$\max_{S_c, M_c, c_{c,t}, a_{c,t+1}} \sum_{t=c}^{c+J-1} \beta^{t-c} u(c_{c,t}) - \eta I(S_c = 1, M_c = 1) \quad (4.1)$$

s.t

$$T^Q = I(M_c = 1, S_c = 1)F(\delta_1 * A^Q(z) + \delta_2) + I(M_c = 0, S_c = 1)F(\delta_1 * A^Q(z)) \quad (4.2)$$

$$T^I = I(M_c = 1, S_c = 1)F(\delta_1 * A^I(z)) + I(M_c = 0, S_c = 1)F(\delta_1 * A^I(z) + \delta_3) \quad (4.3)$$

$$\sum_{t=c}^{c+J-1} \frac{c_{c,t}}{\prod_{j=c}^t R_j} \leq I(S_c = 0) \sum_{t=c}^{c+J-1} \frac{w_t^R}{\prod_{j=c}^t R_j} + I(S_c = 1) \left[ \sum_{t=c}^{c+J_e-1} \frac{-\pi}{\prod_{j=c}^t R_j} + \sum_{t=c+J_e}^{c+J-1} \frac{w_t^I T^I + w_t^Q T^Q}{\prod_{j=c}^t R_j} \right] \quad (4.4)$$

$$a_{c,c+J} \geq 0 \quad (4.5)$$

where  $\beta$  is a discount factor,  $\eta$  represents the disutility of NSE majors,  $I(\cdot)$  is an indicator function that takes the value of 1 if the condition in parentheses is true and 0 otherwise. Equations (4.2) and (4.3) define the mapping rule from ability endowments and educational choices to two types of non-routine tasks, where  $F(\cdot)$  is the cumulative distribution function for a standard normal distribution, and  $\delta_1$ ,  $\delta_2$  and  $\delta_3$  are parameters governing the process of transforming ability endowments into non-routine tasks. These three parameters are

restricted to take positive values to capture two facts: after college education, higher ability agents are able to perform more non-routine tasks, and conditional on endowments agents with an NSE major are able to perform more quantitative tasks and less interactive tasks than agents with other majors. Condition (4.4) represents the budget constrain, where  $R_t$  is the time  $t$  gross return on asset,  $w_t^R$  is the time  $t$  unit price of routine tasks,  $\pi$  and  $J_e$  are respectively the tuition and time cost of college education,  $w_t^I$  is the unit price of interactive tasks, and  $w_t^Q$  the unit price of quantitative tasks.<sup>3</sup> This budget constraint makes clear that agents need to pay both pecuniary tuition cost and non-pecuniary cost of forgone wages to complete college education. Condition (4.5) restricts agents from leaving negative assets behind.

#### 4.2.2 Firm Problem

Given factor prices  $\{w_t^R, w_t^Q, w_t^I\}$ , a representative firm solves the following profit maximization problem.

$$\max_{L_t^R, L_t^Q, L_t^I} A_t (L_t^R)^{\theta_t^R} (L_t^Q)^{\theta_t^Q} (L_t^I)^{\theta_t^I} - w_t^R L_t^R - w_t^Q L_t^Q - w_t^I L_t^I \quad (4.6)$$

where  $L_t^R$ ,  $L_t^Q$ , and  $L_t^I$  are the demand for routine tasks, quantitative tasks, and interactive tasks, respectively.  $A_t$  represents the ability-neutral productivity.  $\theta_t^R$ ,  $\theta_t^Q$ , and  $\theta_t^I$  are the output elasticities of routine tasks, quantitative tasks and interactive tasks, respectively. The production technology is constant returns to scale with  $\theta_t^R + \theta_t^Q + \theta_t^I = 1$ .

#### 4.2.3 Equilibrium

Let  $z \in \mathbf{Z} = [0, 1]$ ,  $S_c \in \mathbf{S} = \{0, 1\}$ ,  $M_c \in \mathbf{M} = \{0, 1\}$ ,  $c_{c,t} \in \mathbf{R}_+$ ,  $a_{c,t+1} \in \mathbf{R}$ ,  $L_t^R \in \mathbf{R}_+$ ,  $L_t^Q \in \mathbf{R}_+$ , and  $L_t^I \in \mathbf{R}_+$ .

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<sup>3</sup>The model assumes that agents are not financially constrained when making educational decisions. This assumption is consistent with findings of [Cameron and Taber \(2004\)](#), [Carneiro and Heckman \(2002\)](#), and [Keane and Wolpin \(2001\)](#).

**Definition** A competitive equilibrium is a collection of factor prices  $\{R_t, w_t^R, w_t^Q, w_t^I\}_{t=1}^\infty$ , production plans  $\{L_t^R, L_t^Q, L_t^I\}_{t=1}^\infty$ , and policy functions  $\{S_c, M_c, c_{c,c}, \dots, c_{c,c+J-1}, a_{c,c+1}, \dots, a_{c,c+J} : \mathbf{Z} \rightarrow \mathbf{S} \times \mathbf{M} \times \mathbf{R}_+^J \times \mathbf{R}^J\}_{c=1}^\infty$  that the following conditions hold.

1. Given prices, agents' decisions solve the optimization problem.
2. Aggregate quantities are consistent with agents' decisions.
3. Given prices, a representative firm maximizes its profits.
4. Labor markets clear.

$$L_t^R = L_t^{RF} + \sum_{t-J+1 \leq c \leq t} \int_z I(S_c(z) = 0) f(z) \quad (4.7)$$

$$L_t^Q = L_t^{QF} + \sum_{t-J+1 \leq c \leq t} \int_z T^Q(z, S_c(z), M_c(z)) f(z) \quad (4.8)$$

$$L_t^I = L_t^{IF} + \sum_{t-J+1 \leq c \leq t} \int_z T^I(z, S_c(z), M_c(z)) f(z) \quad (4.9)$$

where the superscript  $F$  represents the tasks supplied by foreign workers.

### 4.3 SPECIFICATION, CALIBRATION, AND EVALUATION

The model is calibrated to match the 1969 US economy. Data moments are collected from the 1970 Census, the National Longitude Survey of Youth 1979 (NLSY79), and the Digest of Education Statistics. This section focuses on explaining the specification and calibration of several important parameters, and a full list of parameters is reported in Tables 4.2 and 4.3.

#### 4.3.1 Tasks

The amount of routine tasks a worker can perform is normalized as 1, and the amount of non-routine tasks is computed based on the worker's occupation and associated occu-

pational task scores, which are constructed from the 2000 Census and the *O\*NET*. The *O\*NET* database is the nation's primary source of occupational information, and it provides assessment of the importance of different types of tasks on a 1 to 5 scale. This paper utilizes the information of the *O\*NET* 15.0 that is issued in June 2010 and contains task characteristics for 855 occupations.

Table 4.1: Task scores and immigrant shares of skilled workers for selected occupations

Occupation	Interactive	Quantitative	Immigrant share	
			1969	2006
Biological scientists	0.602	0.820	10.7%	18.1%
Computer systems analysts and computer scientists	0.688	0.804	4.7%	22.4%
Economists, market researchers, and survey researchers	0.618	0.833	6.3%	16.3%
Mathematicians and mathematical scientists	0.398	0.892	4.2%	23.3%
Lawyers	0.880	0.619	2.2%	5.7%
Physicists and astronomers	0.445	0.935	20.0%	26.1%
Secondary school teachers	0.801	0.592	2.0%	6.0%
Secretaries	0.605	0.657	6.8%	12.1%
Social workers	0.774	0.499	4.2%	9.7%
Vocational and educational counselors	0.784	0.632	2.3%	7.9%

Data source: 1970 Census, 2007 American Community Survey, and *O\*NET* 15.0

Based on these characteristics, the task scores are computed in three steps. First, for each occupation pick up the scores of resolving conflicts and negotiating with others, communicating with supervisors, peers, or subordinates, communicating with persons outside organization, oral comprehension, written comprehension, oral expression and written expression (indicators for interactive tasks), and the scores of analyzing data or information,



mathematical reasoning, deductive reasoning, inductive reasoning, estimating the quantifiable characteristics of products, events, or information (indicators for quantitative tasks). Second, following the approach of [Peri and Sparber \(2011\)](#), I merge these occupational scores to the native workers in the 2000 Census 1 percent sample, and construct percentile scores for each measure.<sup>4</sup> Third, the interactive task score is calculated as the average score of the seven dimensions that stand for interactive tasks. The quantitative task score is calculated as the average of the five dimensions that represent quantitative tasks. [Table 4.1](#) provides the scores and immigrant shares of skilled workers for selected occupations.

### 4.3.2 Agent Problem

One period in the model is defined as one year in the data. Agents enter the economy at age 18 and exit the economy at age 65. This age structure corresponds to set  $J$  to 47. The cohort size is normalized as 1. The distribution of ability endowments follows a standard bivariate normal distribution with a covariance  $\rho$ , which is set to 0.7911 to match the correlation between the average score of mathematics knowledge and arithmetic reasoning and the average score of paragraph comprehension and word knowledge among those high school age respondents with Armed Forces Qualification Test scores in the NLSY79.

The utility function is specified as  $u(c) = \ln(c)$ . The discount factor is set to 0.95, and the gross return on asset is set to the inverse of the discount factor. Parameters  $\delta_1, \delta_2, \delta_3, \eta$  are jointly calibrated to match four data moments: the skilled share, the ratio of quantitative tasks performed by workers with NSE majors to those performed by workers with other majors, the ratio of interactive tasks completed by workers with other majors to those completed by workers with NSE majors, and the NSE major share.<sup>5</sup>  $Je$  is set to

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<sup>4</sup>The native workers sample only includes full-time-full-year workers aged 18-65 with weekly earnings more than 1/2 of the national minimum wage in 1982.

<sup>5</sup>The two targeted ratios are computed based on the amount of tasks performed by workers who completed college in 1969 and appeared in the 2009 and 2010 American Community Survey (ACS). On average, workers with a NSE major exert 10.6 percent more quantitative tasks but 7.1 percent less interactive tasks than those with other majors. The algorithm is documented in [Appendix A.3](#).

4 to reflect the time cost of college education. The annual tuition cost is set to 31 percent of the routine task unit price to match the ratio of the tuition cost reported in the Digest of Education Statistics to the average wage of unskilled workers in the 1970 Census.

Table 4.2: A-priori parameters

Para.	Value	Source
$J$	47	
$Je$	4	
$\rho$	0.7911	NLSY79
$\beta$	0.95	
$R$	1.05	
$\pi/WL$	0.31	Digest of Education Statistics and Census
$A$	1	Normalization
$\theta^R$	0.79	1970 Census
$\theta^Q$	0.12	1970 Census
$\theta^I$	0.09	1970 Census
$L^{RF}$	2.12	1970 Census
$L^{QF}$	0.26	1970 Census
$L^{IF}$	0.23	1970 Census

### 4.3.3 Immigration

The amount of routine tasks performed by immigrants is equivalent to the number of unskilled immigrant workers in the 1970 Census. The amount of non-routine tasks is computed by aggregating individual occupational scores of skilled immigrant workers. The calculation is weighted by the product of person weights and the number of hours worked last year and adjusted to reflect that the size of each native cohort is 1.

Table 4.3: Calibrated parameters

Para.	Value	Targeted moments	Data	Model
$\delta_1$	0.4617	Skilled share	0.142	0.158
$\delta_2$	0.3306	Quantitative tasks supplied by NSE majors relative to other majors	1.107	1.094
$\delta_4$	0.7970	Interactive tasks supplied by other majors relative to NSE major	1.076	1.085
$\eta$	0.0182	NSE major share	0.159	0.157

#### 4.3.4 Production Technology

The ability-neutral productivity  $A$  is normalized as 1.  $\theta^U$ ,  $\theta^Q$ , and  $\theta^I$  map to the wage shares of three types of tasks, which are computed using the total wage bills paid to each type of tasks. The total wage bill paid to routine tasks are calculated as the product of the average wage and the number of unskilled workers, including both immigrants and natives.<sup>6</sup> The prices of non-routine tasks are estimated from running the following regression.

$$y_{jt} = w_t^I * T_{jt}^I + w_t^Q * T_{jt}^Q + \varepsilon_{jt} \quad (4.10)$$

where  $y_{jt}$  is the skilled wage for person  $j$  in year  $t$ ,  $T_{jt}^I$  and  $T_{jt}^Q$  are respectively this person's interactive and quantitative task scores.  $\varepsilon_{jt}$  represents error terms. The estimated

<sup>6</sup>The wage information is collected from full-time-full-year white male workers. Because the model does not capture the return to work experience, the wage information used by the model is obtained by running the following regression.

$$\ln y_{jt} = \alpha_0 + \alpha_1 I(S_{jt}) + \theta_{experience_{jt}} + \epsilon_{jt}$$

where  $y_j$  is the actual wage for person  $j$  in year  $t$ ,  $I(S_{jt})$  is an indicator for college graduates,  $\theta_{experience_{jt}}$  represents the fixed effect for work experience, and  $\epsilon_{jt}$  is error terms. Following the approach of [Borjas \(2003\)](#), work experience is defined as the number of years that have elapsed since the person completed school. The coefficient  $\alpha_1$  measures the log college premium. Excluding the return to work experience indicates that the unskilled wage is  $\exp(\alpha_0 + \epsilon_{jt})$  and the skilled wage is  $\exp(\alpha_0 + \alpha_1 + \epsilon_{jt})$ .

coefficients  $w_t^I$  and  $w_t^Q$  are respectively the prices for interactive tasks and quantitative tasks in year  $t$ . Thus, the total wage bill paid to the two types of non-routine tasks are calculated as the product of these prices and the corresponding aggregate task scores.

#### 4.3.5 Evaluation

The model is evaluated by comparing the model generated moments with the data moments along two important dimensions that are not targeted. First, the model predicts that the log college premium is 0.36, which is very close to the data counterpart of 0.47. Second, the model predicts the ratio of the quantitative task price to interactive task price is 1.56, which is also very close to the data number of 1.38.

### 4.4 POLICY EXPERIMENTS

This section examines the steady state effects of three policy experiments. The first experiment introduces the changes in both technology and immigration for the period of 1969 to 2006. The second experiment studies the partial effects of technological progress, and the last experiment exploits the partial effects of the immigration shock. Table 4.4 demonstrates the comparison between different steady states.

#### 4.4.1 Technological Progress and Immigration Change

This section constructs a new steady state by changing the technological level and task supplied from immigrants. The shift of production technology is captured by setting the payment shares of different types of tasks  $\theta^R$ ,  $\theta^I$  and  $\theta^Q$  to their 2006 levels, which are respectively 0.50, 0.20, and 0.30. These changes indicate that the technological progress is not only biased towards skilled workers relative to unskilled workers, but also biased

towards quantitative tasks relative to interactive tasks. The immigration shock is modeled by setting  $L^{RF}$ ,  $L^{IF}$ , and  $L^{QF}$  to 5.07, 1.40 and 1.45, respectively.<sup>7</sup> These shifts imply that the US experiences the influxes of both unskilled immigrants and skilled immigrants, and the influx of skilled immigrants supplies more quantitative tasks than interactive tasks.

Table 4.4: Steady state comparison

	Benchmark	Technology& Immigration	Technology	Immigration
	(1)	(2)	(3)	(4)
Skilled share (%)	15.8	40.4	40.0	14.0
NSE major share (%)	15.7	20.7	21.8	13.9

These two exogenous changes raise the relative prices of two types of non-routine tasks. The price increase of quantitative tasks is larger than that of the interactive tasks. As a result, in the new steady state, agents are more likely to attend college and pursue a NSE major. The changes predicted by the model are consistent with the actual changes observed for the period of 1969-2006: the skilled share and NSE major share increased from 15.8 to 33.0 percent and from 15.7 to 17.2 percent, respectively.

#### 4.4.2 Technological Progress

This section studies the partial effects of the technological progress that is described in Section 4.4.1. The responses to this policy experiment are very similar to those of the previous experiment, because technological progress is the dominant factor that affects agent and firm decisions over the past few decades.

<sup>7</sup>The information about the 2006 levels are constructed from the 2007 ACS based the method described Section 3.4.

### 4.4.3 Immigration Change

This section constructs a new steady state by introducing the immigration shock depicted in section 4.4.1. The immigration shock is characterized by the influxes of both skilled immigrants and unskilled immigrants. On one side, the influx of unskilled immigrants pushes up the supply of routine tasks, lowers the relative price of routine tasks, and induces more agents to pursue college education. On the other side, the influx of skilled immigrants raises the supply of non-routine tasks, lowers the relative price of non-routine tasks, and reduces agents' incentives to go to the college. Overall, the effects from skilled immigrants dominate: following the immigration shock, native-born Americans will be less likely to take college education and become skilled workers. The immigration shock also reduces the NSE major share, because the influx of skilled immigrants supplies more quantitative tasks than interactive tasks.

## 4.5 CONCLUSION

Considering that education is a multidimensional choice, this paper studies the long-term effects of technological progress and immigration shocks on native-born Americans' educational decisions. Results suggest that technological progress raises natives' incentives to complete college education and pursue a NSE major, but immigration shock has the opposite effects. As the next step, the proposed model could be used to study the welfare implications of different immigration reforms. The advantage of this model is that it captures native-born Americans responses via a multidimensional educational choice.

## **APPENDIX**

### **ALGORITHM**

#### **A.1 CHAPTER 2**

A stationary competitive equilibrium is solved using the following six steps.

1. Discretize the state space for health capital and assets by choosing a finite number of grids: 21 grids for health capital and 50 grids for asset holdings.
2. Guess prices  $r, R, w, P_a, P_w(j)$ , a tax rate  $\tau$  and a transfer  $Tr$ .
3. Solve the model backwards for optimal policy functions at each grid point.
4. Simulate decisions of 10,000 agents by using the initial distribution and the policy functions derived in step 2.
5. Update prices, the tax rate and the transfer using firm's first order conditions, insurance firm's zero profit conditions, the government budget constraint, and the rule of transfers.
6. Repeat from step 3 until convergence.

#### **A.2 CHAPTER 3**

The model is calibrated using the following steps.

1. Discretize the continuous state variables: the stochastic shock is discretized by three grids using the method of Tauchen (1986), and the permanent productivity component is discretized using five equal probability states.
2. Guess a set of parameter values.
3. Solve the individual problem backwards for policy functions.
4. Simulate decisions of 100,000 agents using the policy functions.
5. Compute aggregate statistics and update the guess of parameters.
6. Repeat from step 3 until convergence.

### **A.3 CHAPTER 4**

An equilibrium is solved using the following steps.

1. Simulate a sample of 10,000 agents by taking repeated random draws from the ability distribution.
2. Guess prices.
3. Simulate optimal decisions for the 10,000 agents using their ability endowments and the price system.
4. Compute aggregate quantities and update prices.
5. Repeat from step 3 until convergence.



## BIBLIOGRAPHY

- Acemoglu, Daron**, “Technical Change, Inequality, and the Labor Market,” *Journal of Economic Literature*, 2002, 40, 7–72.
- **and David Autor**, “What does human capital do? A review of Goldin and Katz’s the race between education and technology,” *NBER Working Paper*, 2012.
- Aguiar, Mark and Erik Hurst**, “Deconstructing Life Cycle Expenditure,” *Journal of Political Economy*, 2013, 121 (3), 437 – 492.
- Aiyagari, S. Rao**, “Uninsured Idiosyncratic Risk and Aggregate Saving,” *The Quarterly Journal of Economics*, 1994, 109 (3), pp. 659–684.
- Aizawa, Naoki and Hanming Fang**, “Equilibrium Labor Market Search and Health Insurance Reform,” *NBER Working Paper*, 2013.
- Ales, Laurence, Roozbeh Hosseini, and Larry E Jones**, “Is There “Too Much” Inequality in Health Spending Across Income Groups?,” *NBER Working Paper*, 2012.
- Arcidiacono, Peter, V Joseph Hotz, and Songman Kang**, “Modeling college major choices using elicited measures of expectations and counterfactuals,” *Journal of Econometrics*, 2012, 166 (1), 3–16.
- Auerbach, Alan J. and Laurence J. Kotlikoff**, “Life insurance of the elderly: adequacy and determinants,” in “Health, and Income among the Elderly,” Washington, DC: Brookings Institution, 1987.
- **and –**, “The adequacy of life insurance purchases,” *Journal of Financial Intermediation*, 1991, 1 (3), 215 – 241.
- Autor, David**, “The unsustainable rise of the disability rolls in the United States: Causes, consequences, and policy options,” *NBER Working Paper*, 2011.

- **and Mark Duggan**, “The Growth in the Social Security Disability Rolls: A Fiscal Crisis Unfolding,” *The Journal of Economic Perspectives*, 2006, *20* (3), 71–96.
- Autor, David H., Frank Levy, and Richard J. Murnane**, “The Skill Content of Recent Technological Change: An empirical exploration,” *Quarterly Journal of Economics*, 2003, *118* (4), 1279–1333.
- **, Lawrence F. Katz, and Alan B Krueger**, “Computing inequality: have computers changed the labor market?,” *The Quarterly Journal of Economics*, 1998, *113* (4), 1169–1213.
- Autor, David H, Lawrence F Katz, and Melissa S Kearney**, “Trends in US wage inequality: Revising the revisionists,” *The Review of Economics and Statistics*, 2008, *90* (2), 300–323.
- Baicker, Katherine, Sarah L Taubman, Heidi L Allen, Mira Bernstein, Jonathan H Gruber, Joseph P Newhouse, Eric C Schneider, Bill J Wright, Alan M Zaslavsky, and Amy N Finkelstein**, “The Oregon experiment-effects of Medicaid on clinical outcomes,” *New England Journal of Medicine*, 2013, *368* (18), 1713–1722.
- Ben-Porath, Yoram**, “The production of human capital and the life cycle of earnings,” *The Journal of Political Economy*, 1967, *75* (4), 352–365.
- Bernheim, B. Douglas**, “How Strong Are Bequest Motives? Evidence Based on Estimates of the Demand for Life Insurance and Annuities,” *Journal of Political Economy*, 1991, *99* (5), pp. 899–927.
- **, Katherine Grace Carman, Jagadeesh Gokhale, and Laurence J. Kotlikoff**, “Are Life Insurance Holdings Related to Financial Vulnerabilities?,” *Economic Inquiry*, 2003, *41* (4), 531–554.
- Bewley, Truman F.**, “Stationary Monetary Equilibrium with a Continuum of Independently Fluctuating Consumers,” *Contributions to mathematical economics in honor of Gérard Debreu*, 1986, p. 79.
- Borjas, George J.**, “The Labor Demand Curve Is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market,” *The Quarterly Journal of Economics*, 2003, *118* (4), 1335–1374.
- Borjas, George J**, “Immigration in High-Skill Labor Markets,” *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, 2009, p. 131.

- Borjas, GJ**, “The labor-market impact of high-skill immigration,” *American Economic Review*, 2005, 95 (2), 56–60.
- Butcher, Kristin F. and David Card**, “Immigration and Wages: Evidence from the 1980’s,” *The American Economic Review*, 1991, 81 (2), 292–296.
- Cameron, Stephen V. and Christopher Taber**, “Estimation of Educational Borrowing Constraints Using Returns to Schooling,” *Journal of Political Economy*, 2004, 112 (1), 132 – 182.
- Card, D and J DiNardo**, “Do immigrant inflows lead to native outflows?,” *American Economic Review*, 2000, 90 (2), 360–367.
- Carneiro, Pedro and James J. Heckman**, “The Evidence on Credit Constraints in Post-Secondary Schooling,” *Economic Journal*, 2002, 112 (482), 705 – 734.
- CBO**, “An Analysis of Health Insurance Premiums Under the Patient Protection and Affordable Care Act,” 2009.
- , “Estimates for the Insurance Coverage Provisions of the Affordable Care Act Updated for the Recent Supreme Court Decision,” 2012.
- , “The Budget and Economic Outlook: 2014 to 2024,” 2014.
- Chambers, Matthew S and Don Edward Schlagenhauf**, “Husbands Might Really Be That Cheap,” *Working Paper*, 2004.
- Conesa, Juan C and Dirk Krueger**, “Social security reform with heterogeneous agents,” *Review of Economic Dynamics*, 1999, 2 (4), 757–795.
- Conesa, Juan C. and Dirk Krueger**, “Social Security Reform with Heterogeneous Agents,” *Review of Economic Dynamics*, 1999, 2 (4), 757–795.
- , **Sagiri Kitao, and Dirk Krueger**, “Taxing Capital? Not a Bad Idea after All!,” *American Economic Review*, September 2009, 99 (1), 25–48.
- Córdoba, Juan Carlos and Marla Ripoll**, “Beyond Expected Utility in the Economics of Health and Longevity,” *Working paper*, 2013.
- Courtemanche, Charles J and Daniela Zapata**, “Does Universal Coverage Improve Health? The Massachusetts Experience,” *NBER working paper*, 2012.
- Cristia, Julian P.**, “The Empirical relationship between lifetime earnings and mortality,” *CBO*, 2007.

- Duggan, Mark and Scott A Imberman**, “Why are the disability rolls skyrocketing? The contribution of population characteristics, economic conditions, and program generosity,” in “Health at older ages: The causes and consequences of declining disability among the elderly,” University of Chicago Press, 2009, pp. 337–379.
- Duleep, Harriet Orcutt**, “Measuring the Effect of Income on Adult Mortality Using Longitudinal Administrative Record Data,” *The Journal of Human Resources*, 1986, 21 (2), pp. 238–251.
- Eberhard, Juan**, “Immigration, human capital and the welfare of natives,” *Working Paper*, 2012.
- Ehrlich, Isaac and Hiroyuki Chuma**, “A Model of the Demand for Longevity and the Value of Life Extension,” *Journal of Political Economy*, 1990, 98 (4), pp. 761–782.
- Feldstein, Martin S.**, “The Welfare Loss of Excess Health Insurance,” *Journal of Political Economy*, 1973, 81 (2), pp. 251–280.
- Feng, Zhigang and Hui He**, “Welfare Analysis of Obamacare,” *Working paper*, 2013.
- Finkelstein, Amy, Sarah Taubman, Bill Wright, Mira Bernstein, Jonathan Gruber, Joseph P Newhouse, Heidi Allen, Katherine Baicker et al.**, “The Oregon Health Insurance Experiment: Evidence from the First Year,” *The Quarterly Journal of Economics*, 2012, 127 (3), 1057–1106.
- Fischer, Stanley**, “A Life Cycle Model of Life Insurance Purchases,” *International Economic Review*, 1973, 14 (1), pp. 132–152.
- Fitzgerald, John**, “The Effects of Social Security on Life Insurance Demand by Married Couples,” *The Journal of Risk and Insurance*, 1987, 54 (1), pp. 86–99.
- Friedberg, Rachel M.**, “The Impact of Mass Migration on the Israeli Labor Market,” *The Quarterly Journal of Economics*, 2001, 116 (4), 1373–1408.
- Goldin, Claudia and Lawrence F Katz**, “The race between education and technology: the evolution of US educational wage differentials, 1890 to 2005,” *NBER Working Paper*, 2007.
- Grossman, Michael**, *The demand for health: a theoretical and empirical investigation*, New York: Columbia Univ. Press (for NBER), 1972.
- , “On the concept of health capital and the demand for health,” *The Journal of Political Economy*, 1972, 80 (2), 223–255.

- , “The human capital model,” *Handbook of health economics*, 2000, *1*, 347–408.
- Gruber, Jonathan**, “Covering the Uninsured in the United States,” *Journal of Economic Literature*, 2008, *46* (3), pp. 571–606.
- **and Ebonya Washington**, “Subsidies to employee health insurance premiums and the health insurance market,” *Journal of Health Economics*, 2005, *24* (2), 253–276.
- Guvenen, Fatih and Burhanettin Kuruscu**, “Understanding the evolution of the US wage Distribution: a theoretical analysis,” *Journal of the European Economic Association*, 2012, *10* (3), 482–517.
- Hall, Robert E and Charles I Jones**, “The value of life and the rise in health spending,” *The Quarterly Journal of Economics*, 2007, *122* (1), 39–72.
- Halliday, Timothy J, Hui He, and Hao Zhang**, “Health Investment over the Life-Cycle,” *Working paper*, 2012.
- Heckman, James J, Lance Lochner, and Christopher Taber**, “Explaining Rising Wage Inequality: Explanations With A Dynamic General Equilibrium Model of Labor Earnings With Heterogeneous Agents,” *Review of Economic Dynamics*, 1998, *1* (1), 1–58.
- Hong, Jay H. and José-Víctor Ríos-Rull**, “Social security, life insurance and annuities for families,” *Journal of Monetary Economics*, 2007, *54* (1), 118 – 140.
- **and –**, “Life Insurance and Household Consumption,” *American Economic Review*, September 2012, *102* (7), 3701–30.
- Hosseini, Roozbeh**, “Adverse Selection in the Annuity Market and the Role for Social Security,” *Working paper*, 2008.
- Hubbard, R. Glenn and Kenneth L. Judd**, “Social Security and Individual Welfare: Precautionary Saving, Borrowing Constraints, and the Payroll Tax,” *The American Economic Review*, 1987, *77* (4), 630–646.
- Huggett, Mark**, “The Risk-Free Rate in Heterogeneous-Agent Incomplete-Insurance Economies,” *Journal of Economic Dynamics and Control*, 1993, *17* (5-6), 953 – 969.
- Imorohoroğlu, Ayşe, Selahattin Imorohoroğlu, and Douglas H. Joines**, “A life cycle analysis of social security,” *Economic Theory*, 1995, *6* (1), 83–114.
- Imorohoroğlu, Selahattin and Sagiri Kitao**, “Social Security Reforms: Benefit Claiming, Labor Force Participation, and Long-Run Sustainability,” *American Economic Journal: Macroeconomics*, 2012, *4* (3), 96–127.

- Janicki, Hubert**, “Distributional Effects of Public Health Insurance Reform,” *Working Paper*, 2012.
- Jr, John E Ware, Mark Kosinski, and Susan D Keller**, “A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity,” *Medical care*, 1996, *34* (3), 220–233.
- Jr, Robert E Lucas**, “Macroeconomic Priorities,” *American Economic Review*, 2003, *93* (1), 1–14.
- Jung, Juergen and Chung Tran**, “Market Inefficiency, Insurance Mandate and Welfare: US Health Care Reform 2010,” *Working paper*, 2011.
- Katz, Lawrence F. and Kevin M. Murphy**, “Changes in relative wages, 1963-1987: supply and demand factors,” *The Quarterly Journal of Economics*, 1992, *107* (1), 35.
- Keane, Michael P. and Kenneth I. Wolpin**, “The Effect of Parental Transfers and Borrowing Constraints on Educational Attainment.,” *International Economic Review*, 2001, *42* (4), 1051.
- King, Miriam, Steven Ruggles, Trent Alexander, Sarah Flood, Katie Genadek, Matthew Schroeder, Brandon Trampe, and Rebecca Vick**, “Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. [Machine-readable database].,” *Minneapolis: University of Minnesota*, 2010.
- Kitagawa, Evelyn Mae and Philip Morris Hauser**, *Differential mortality in the United States: a study in socioeconomic epidemiology*, Harvard University Press, 1973.
- Kitao, Sagiri**, “A life-cycle model of unemployment and disability insurance,” *Working paper*, 2013.
- Krebs, Tom, Moritz Kuhn, and Mark Wright**, “Human Capital Risk, Contract Enforcement, and the Macroeconomy,” *Working Paper*, 2012.
- Lewis, Ethan G**, “Immigrant-native substitutability: The role of language ability,” *NBER Working Paper*, 2011.
- Lewis, Frank D.**, “Dependents and the Demand for Life Insurance,” *The American Economic Review*, 1989, *79* (3), pp. 452–467.
- Maestas, Nicole, Kathleen Mullen, and Alexander Strand**, “Disability Insurance and Healthcare Reform: Evidence from Massachusetts,” *Working Paper*, 2012.

- Mulligan, Casey B**, “Average Marginal Labor Income Tax Rates under the Affordable Care Act,” *NBER Working Paper*, 2013.
- Murphy, Kevin M and Robert H Topel**, “The Value of Health and Longevity,” *Journal of Political Economy*, 2006, 114 (5).
- Nardi, Mariacristina De, Selahattin İmorohoroğlu, and Thomas J. Sargent**, “Projected U.S. Demographics and Social Security,” *Review of Economic Dynamics*, 1999, 2 (3), 575–615.
- Newhouse, Joseph P. and Rand Corporation**, *Free for all?: lessons from the RAND health insurance experiment*, Harvard University Press, 1993.
- Neymotin, Florence**, “Immigration and its effect on the college-going outcomes of natives,” *Economics of Education Review*, 2009, 28 (5), 538–550.
- Pashchenko, Svetlana and Ponpoje Porapakkarm**, “Quantitative analysis of health insurance reform: Separating regulation from redistribution,” *Review of Economic Dynamics*, 2013, 16 (3), 383 – 404.
- Peri, G. and C. Sparber**, “Highly Educated Immigrants and Native Occupational Choice,” *Industrial Relations: A Journal of Economy and Society*, 2011, 50 (3), 385–411.
- Peri, Giovanni and Chad Sparber**, “Task Specialization, Immigration, and Wages,” *American Economic Journal: Applied Economics*, 2009, 1 (3), 135–69.
- Rask, Kevin**, “Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences,” *Economics of Education Review*, 2010, 29 (6), 892–900.
- Restuccia, Diego and Guillaume Vandenbroucke**, “The evolution of education: A macroeconomic analysis,” *International Economic Review*, 2013, 54 (3), 915–936.
- Ruggles, Steven, Trent Alexander, Katie Genadek, Ronald Goeken, Matthew Schroeder, and Matthew Sobek**, “Integrated Public Use Microdata Series, Current Population Survey: Version 5.0. [Machine-readable database].,” *Minneapolis: University of Minnesota*, 2010.
- Social Security Administration**, *Annual Statistical Report on the Social Security Disability Insurance Program*, Office of Retirement and Disability Policy, Office of Research, Evaluation, and Statistics, 2000-2011.
- Stratmann, Thomas**, “What Do Medical Services Buy? Effects of Doctor Visits on Work Day Loss,” *Eastern Economic Journal*, 1999, 25 (1), 1.

- Suen, Richard MH**, “Technological advance and the growth in health care spending,” *Working paper*, 2006.
- Taubman, Sarah L, Heidi L Allen, Bill J Wright, Katherine Baicker, and Amy N Finkelstein**, “Medicaid Increases Emergency-Department Use: Evidence from Oregon’s Health Insurance Experiment,” *Science*, 2014, p. 1246183.
- Tsujiyama, Hitoshi**, “Implications of Health Care Reform for Inequality and Welfare,” *Working Paper*, 2013.
- Yaari, Menahem E.**, “Uncertain Lifetime, Life Insurance, and the Theory of the Consumer,” *The Review of Economic Studies*, 1965, 32 (2), pp. 137–150.
- Yogo, Motohiro**, “Portfolio choice in retirement: Health risk and the demand for annuities, housing, and risky assets,” *NBER Working Paper*, 2012.
- Zhao, Kai**, “Social Security and the Rise in Health Spending: A Macroeconomic Analysis,” *Working paper*, 2012.